TEXTILE RESEARCH JOURNAL

VOLUME XXIV June, 1954 *NUMBER 6*

National Cotton Council of America Fifth Cotton Research Clinic

PUBLICATION OF

TEXTILE RESEARCH INSTITUTE

Editorial Office: 10 East 40th Street, New York 16, N. Y.

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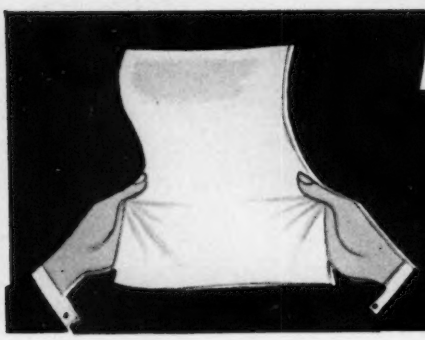

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TEXTILE RESEARCH JOURNAL

VOL. XXIV, No. 6 June, 1954

The Fifth Cotton Research Clinic

of the

National Cotton Council of America

Pinehurst, North Carolina

February 17, 18, 19, 1954

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TEXTILE RESEARCH JOURNAL, published monthly at Prince and Lemon Streets, Lancaster, Pa., is devoted to the interest of research in textile and allied industries. It is published by Textile Research Institute.

Entered as second-class matter, April 27, 1945, at the post office at Lancaster, Pa., under the Act of August 24, 1912. Accepted for mailing at special rate of postage provided for in paragraph (d-2), Section 34.40, P. L. & R. of 1948, authorized May 9, 1950.

Manuscripts and communications should be sent to the editorial office, 10 East 40th Street, New York 16, N. Y.

Subscription rates: $15.00 per year; additional for postage, 50 cents to Canada, $1.00 to all other countries. Single copies, $1.50 each.

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Foreword

The publication in TEXTILE RESEARCH JOURNAL *of the proceedings of the Cotton Research Clinic sponsored by the National Cotton Council held at Pinehurst, North Carolina, this year is another illustration of the fine cooperation that has slowly but surely been developing in the textile industry in recent years.*

The Research Clinic started with an idea in the Technical Service Division of the National Cotton Council some years ago, and the initial meeting held in Washington was composed entirely of scientists. Through the past several years there has been a gradual evolution in the group attending the Clinic and registration at Pinehurst this year showed a fine cross section of cotton mill management, cotton trade, textile machinery manufacturers, scientists and engineers of every description.

The fine quality of the papers presented each year and the interest that has developed in the Clinic is a tribute in itself to the good work of the personnel of the National Cotton Council, the speakers, and chairmen who have given of their time and energy to participate in the program.

The last two years have seen an international flavor to the program and we have every hope that our friends abroad will continue to participate from time to time. We would like to take this opportunity to emphasize the importance of the practical information in the papers not only to people directly concerned with mill operations and processes but also to all scientists and research personnel engaged in laboratory research pertaining to textiles.

We sincerely hope that these proceedings will be of interest and value to the reader and that it will be possible for the Clinic to continue to serve in the fine capacity of bringing together all interested parties to the end that the gap may be narrowed between research and manufacturing; that the research man may better understand the problems connected with manufacturing and that it is necessary to keep his feet on the ground; and that the operating man in the plant may for his part develop a state of mind that will tune him in better with the research man and new ideas, so that both members of the team may make greater contributions in the future.

M. EARL HEARD
Vice-President, In Charge of Research
West Point Manufacturing Company
Shawmut, Alabama

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TEXTILE RESEARCH JOURNAL

VOL. XXIV, NO. 6 JUNE, 1954

Measurement of the Nepping Potential of Cotton*

J. F. Bogdan†

North Carolina State College, School of Textiles, Raleigh, North Carolina

THE ABILITY to evaluate rapidly and accurately, from a small sample, the tendency of a cotton to form neps in processing has been long desired by those concerned with the various aspects of cotton: its breeding, growing, distribution, and manufacture into yarn and fabric. A cotton bred for improved qualities of fiber length, strength, maturity, and fineness may fail miserably in manufacturing if it also possesses a high "flab factor"—that undesirable property which causes one cotton to curl up and die when subjected to the rigors of current manufacturing methods, while at the same time another cotton, with identical fiber characteristics as measured by current tests, will resist the tangling forces.

The problem of evaluating this property has been recognized for a long time. Its solution would bring such valuable rewards that the United States Department of Agriculture, through provisions of the Research and Marketing Act, gave the project the necessary priority for its contracting at North Carolina State College.

Simple mechanics can explain why a coarse fiber is more resistant to nepping than a fine fiber; why a mature fiber, with a rounder cross section, is more resistant to nepping than an immature fiber, with its flat, ribbon-like cross section. But why do fibers with identical degrees of fineness and maturity differ in this respect? The answer must lie in structural differences which are not usually measured. One may consider identical metals in two forms which have the same weight per unit length—one in the form of a rod and one in the form of a chain. The difference in the ease with which they can be bent and entangled is apparent.

Anyone who has observed the effects of reprocessing on the quality of the stock has noted the increase of tangled fibers with the amount of mechanical treatment. Like the stonecutter's granite, a fiber may resist forty-nine blows, only to be shattered into a nep at the fiftieth.

Operation of Nepotometer

The final model of the instrument for predicting the nepping potential of cotton (Figure 1) is based on this principle of repetitive action on the same fibers. It also incorporates the actions of carding and stripping found in a full-scale cotton card.

Basically, the Nepotometer consists of a feeding arrangement, three rolls covered with metallic card

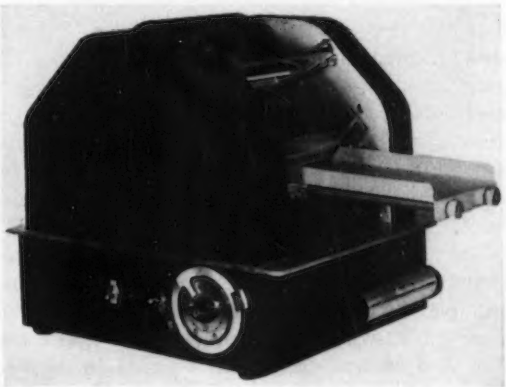

FIG. 1. *The Nepotometer.*

*A report of work done under contract with the U. S. Department of Agriculture and authorized by the Research and Marketing Act. The contract was supervised by the Southern Regional Research Laboratory, Bureau of Agricultural and Industrial Chemistry.

†Director of Processing Research.

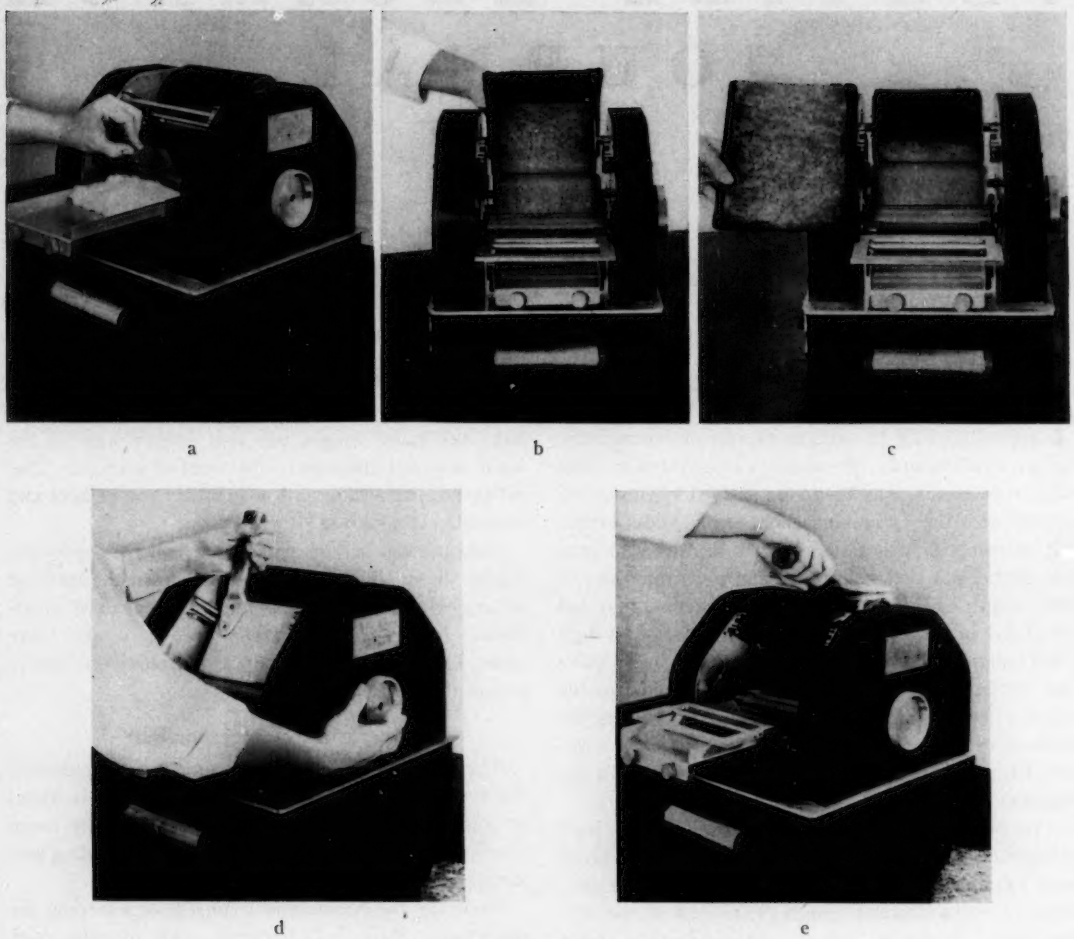

FIG. 2. *Steps in the operation of the Nepotometer.*

clothing to manipulate the cotton, a presser plate to prevent fiber plucking at one of the fiber transfer points, a preset timer to insure a standard degree of manipulation, a means of transferring a sample of the web for inspection, and the necessary means of actuation in the working direction and in the reverse direction for the purpose of clearing the instrument after the test is completed.

The test method consists of first obtaining an accurately weighed, 25-grain sample which is representative of the bale of cotton to be evaluated. This is carded between a pair of hand cards into a pad 5 in. × 5 in., and the sample is placed on the feed table and tucked under the feed roll (Figure 2a). The rotation of the mechanism begins in the working direction with the timer set for 4 min. At the end of this time the machine stops automatically. The presser plate is removed, and a piece of cardboard, 6 in. × 10 in., covered with black velveteen is placed in contact with the web at the back of the top roll. By maintaining contact with the web as the board is swung forward (Figure 2b), the sample is made to adhere to the pile of the velveteen. The sample web is broken at the edge by swinging the board away from the roll (Figure 2c). The sample is set aside, and the first bottom cylinder is stripped of excess material by rotating the cylinder by hand in the reverse direction while a hand-stripper is held in contact with the cylinder (Figure 2d). A reverse switch permits the three cylinders to rotate in the reverse

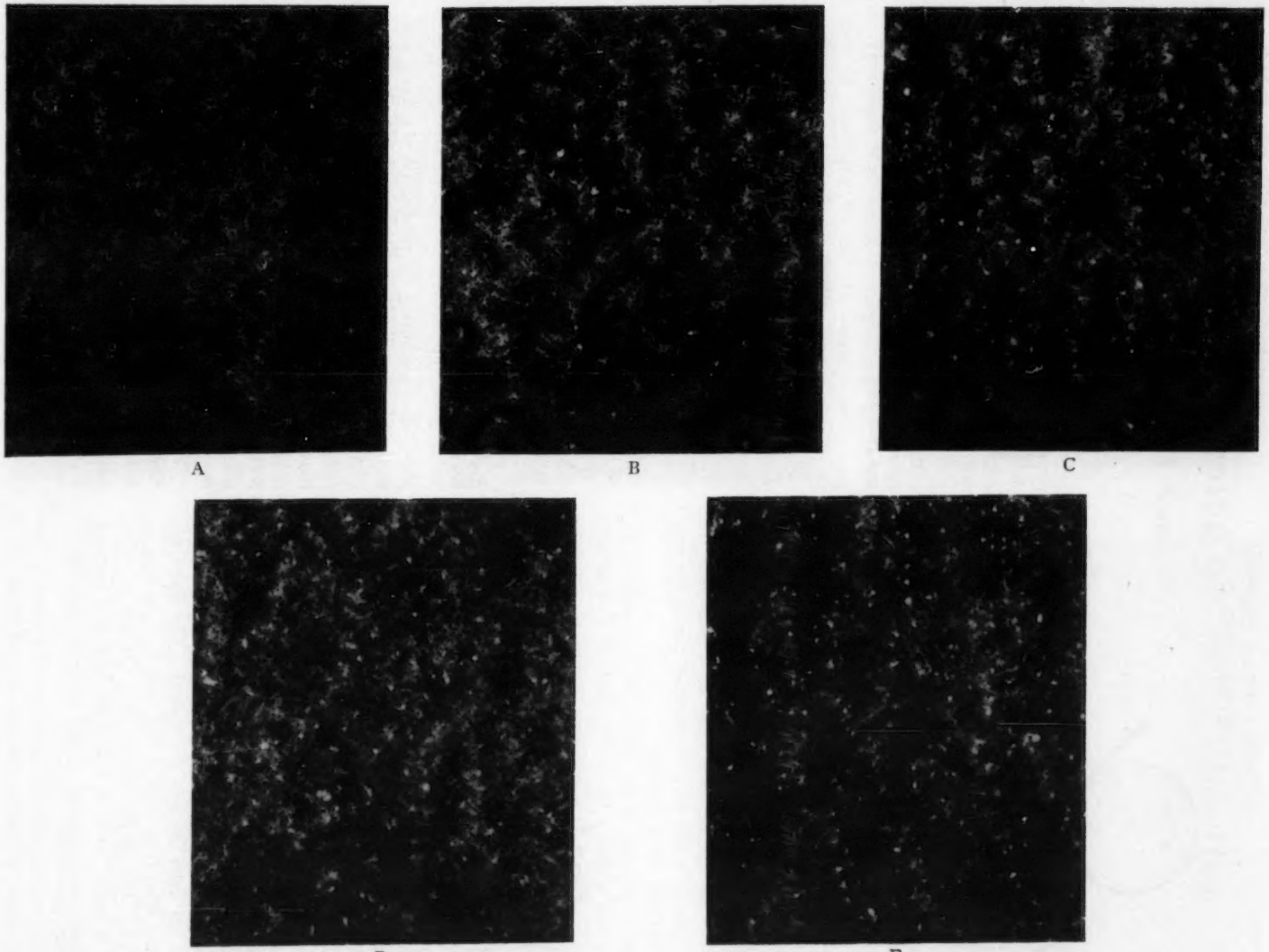

FIG. 3. *Tentative nep standards representing degrees of neppiness.* A = *low;* E = *high.*

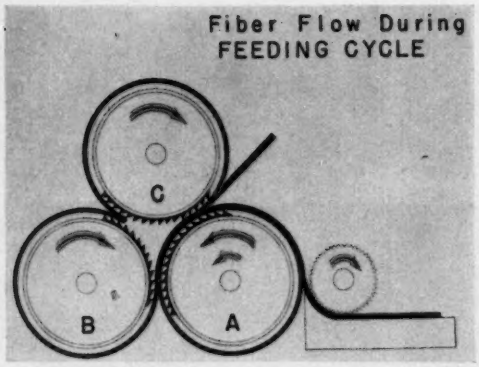

FIG. 4. *Cotton fringe is torn away from feed roll by rotation of cylinder* A. *Carding action occurs when fibers are transferred to roll* B.

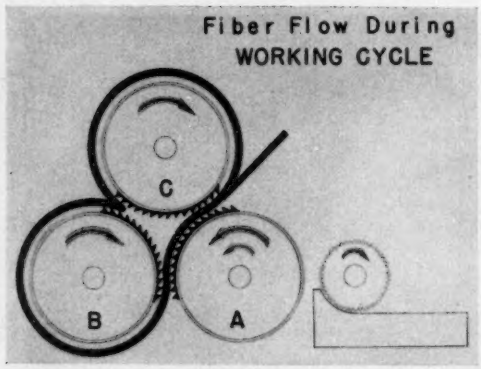

FIG. 5. *Repetitive action principle is applied during operation. Fibers are worked from roll* C *to* A *to* B *and back to* C.

direction from that used during the working cycle, and all of the cotton remaining on the bottom cylinder is transferred by the action of the wires to the top cylinder, where it is removed readily with a hand-stripper (Figure 2e). After the presser plate is replaced the instrument is ready to accommodate the next sample, which may be prepared during the time that the first test is running.

The appearance of the sample web is compared for neppiness against a set of five standard photographs of webs (Figure 3) which show a range of neppiness from very low to very high. The average weight per unit area is approximately the same as that for a card web weighing 50 grains per linear yard.

Direction of fiber flow during the feeding cycle is shown in Figure 4. The fringe of cotton is torn away from the nip of the feed roll and feed plate by the rotation of cylinder *A*, which has a relatively high surface speed. Cylinders *B* and *C* have the same surface speed, lower than *A*. As the fibers, held on the wire teeth of *A* pass roll *B*, some fibers are transferred to *B* in a carding action, while others remain on *A*. Those fibers which are transferred are removed by cylinder *C* through a stripping action and, in turn, from *C* to *A* by a stripping action.

Figure 5 illustrates the fiber flow after all the material has been fed into the system. The fibers are worked from *C* to *A* to *B* and back to *C* as long as desired. The presser shown near the nip of cylinders *A* and *C* tends to retard the very easy transfer of fibers from cylinder *C* and prevents plucking of fibers, thus permitting the production of a more uniform web.

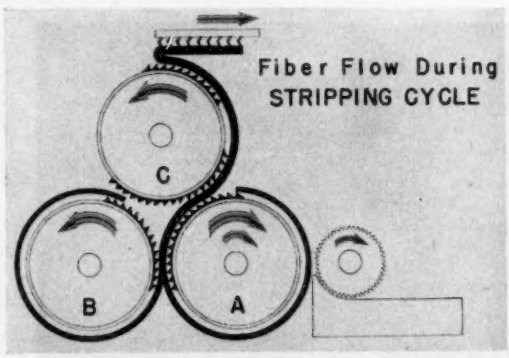

FIG. 6. *Reversing Nepotometer makes stripping easy. Roll* B *strips fibers from underside of* C. *Roll* A *brushes fibers from roll* B *onto roll* C.

At the end of the test, when it is desired to clear the instrument, the rolls are reversed; the fiber flow is illustrated in Figure 6. Cylinder *B* strips all fibers from the underside of *C*. Cylinder *A*, because of its higher surface speed, brushes fibers from *B* and impales them on the points of cylinder *C*, from which they are removed by a hand-stripper.

The excellent design of the present model of the Nepotometer is due to the efforts of Professor C. M. Asbill, Head of the Machine Development Department of the School of Textiles, who, with the writer, is coinventor of the instrument.

Influence of Processing on Nep Formation

R. H. Souther*

Cone Mills Corporation, Greensboro, North Carolina

IN order to meet the conditions imposed by a competitive market, increasing pressure is being put on the mills to reduce the neps in finished cloth. Our research indicates that significant reduction in neps can be achieved by better processing of cotton at the cards, in the gin and other processing machinery, as well as in proper blending of the raw cotton to minimize fineness as a factor.

This paper is primarily concerned with the influence of processing on and the elimination of nep formation.

In the literature published to date, covered remarkably well in the review by Professor Bogdan [6], voluminous information on the number of neps in card web and yarn can be found, and a little on neps in fabrics, because it is relatively easy to count the neps at these stages of processing. Considerable work has been done in relating fiber properties to nep formation [3] and in predicting which fibers, such as fine and long, are more apt to produce neppiness [11]. To avoid neppiness at any cost, it has even been suggested that the comparatively shorter and coarser types be cultivated in some cotton growing areas where the trouble is persistent [1]. Much research has been published on the influence of processing on nep formation [4, 5, 8, 10, 15], but very little on the extent and frequency of occurrence. A new approach in this problem of evaluating old and new processing machinery in connection with waste analyses has shown some rather interesting and unexpected results, which will be discussed in this paper.

The cards are conceded to be the most important step in processing with regard to neps [7]. Many investigators have stated that the cards form neps. In a recent report on the use of a new method of preparing bulk cotton for nep count, results indicated the openers, pickers, cards, and drawing machinery all added a few neps to the stock [13]. Our results differ in magnitude of nep count as well as in cards decreasing rather than increasing neps, assuming that the cards are in good order. Other investigators indicated that carding does not increase neps but concentrates a few of them for elimination as waste [9].

Nep Quality Control System

For several years, our plants have been using a quality control system of checking each stage of processing in an effort to reduce the number of neps as much as possible and to maintain highest quality in cleanliness of the finished fabric. In setting up this quality control system, the same method for counting neps at different processing stages was used as for counting neps in raw cotton [2]. This method is very simple, accurate, and requires very little time. It is the conventional method of separating the fibers with a spatula and counting the number of neps in a one-grain sample. If desired, the neps can be picked out of the samples and weighed, in order to determine the percent neps by weight. For our purposes, the number of neps in the sample gives sufficient information. This method has been used for about ten years, and good correlations were found on a number of tests made on the same sample and between at least 10 different technicians, as well as with an outside laboratory [14]. Excellent correlations were obtained between our laboratory and the U. S. D. A. laboratory at Clemson with card web nep counts per 36 sq. in., showing 19, 11, 9 and 19, 8, 8, respectively. These results are lower than those obtained in the 17-Mill Test [8]. This method of counting neps has been useful in determining what effect the openers, picker, cards, and drawing machinery have on nep formation.

A nep count/36 sq. in. in card web is preferred to nep count/100 sq. in. in order to get a direct correlation with neps/grain, since 36 sq. in. of web approximates 1 grain weight of sliver in most of these processes. By using the same basis for comparison, the number of neps per grain (or 36 sq. in. in card web), it can be seen how the stock has been affected through successive processing stages.

After several years experience with this nep quality control system, it was found that the number of neps is increased by the various processing stages from

* Research Director.

raw cotton in bales through the pickers. Each stage of processing up to and including the pickers tends to cause or produce more neps in the stock. However, when the stock, or picker lap, reaches the cards, this operation removes neps from the stock, and the drawing operations gradually increase the number of neps.

As is well known, all cards do not reduce the number of neps by the same amount. In quality control work, nep counts are made on card web from each card in the plant at the same time. (Variations due to stripping are comparatively low.) Seldom does a card have the same number of neps in card web as in the lap going into the card. Most cards reduce the number of neps in card web considerably. When cards are found that are taking out only a few neps, they are quickly adjusted; either cards are reset, ground, new card clothing installed, or other adjustment made. A detailed report of this card web nep count is sent to the card room foreman so that proper action can be taken on any particular card with abnormally high nep count and the needed adjustments made to bring it in line. In turn, the foreman also charts the nep counts and gives special attention to those cards repeatedly sluggish in reducing neps. Special attention is also given to reducing average nep count to produce best quality cloth.

Importance of Card Maintenance

Results in these processes have shown that better control of neps can be obtained by maintenance and adjustment of cards, since fineness and other fiber properties have been practically eliminated by good buying and proper blending. By proper adjustment of cards the nep count in card web can be reduced from as high as 29 down to as low as 6 neps/36 sq. in. In contrast, differences in fiber properties, such as fineness (down to 3.5 μg./in.), maturity, irrigated or raingrown, were found to vary the nep count only about 30%, or from an average of 10 up to 13 neps/36 sq. in.

For example, the cotton comes from the boll with about 2 neps/grain and from the gin with approximately 18 neps/grain. Through opening machinery and pickers, about 16 or 17 more neps/grain, or about 100% more neps, are added to make a total of 33–35 neps/grain. If the card is in excellent condition, the neps may be reduced as low as 6 neps/grain, with an average of about 11 neps/grain (averaging all the cards in the plant); however, if the card is in poor condition, there are few neps taken out, thus giving a web with about 29 neps/grain, an increase of nearly 200% above average, or 5 to 6 times more than the increase caused by fineness of cotton. Such a card would be rated with a very low efficiency, and with poor stripping and extremely low grade or fine cotton it would be possible to obtain a negative efficiency, or more neps left in than removed by clothing. This condition has not been found, however, in the hundreds of cards tested in the 5 different processes shown in Table I. It may be observed that the elimination of vertical openers or superior cleaners has little effect on nep count in lap in these tests, and revolutionary changes may be needed to achieve reduction in these stages.

As a means of rating card nep removal efficiency, the writer proposes the following formula:

$$\frac{(\text{lap neps/grain}) - (\text{web neps/grain})}{\text{lap neps/grain}} \times 100 = \% \text{ efficiency.}$$

However, a correcting value using constant of 6 neps/grain should be deducted from the web neps/grain for weighting purposes in measuring plant efficiency on a grading basis for card efficiency.

In this rating, a process can be graded with proper allowance for neppiness of raw cotton and limitations of machinery. The card room foremen have great responsibilities, and the card efficiency grades above 80% indicate that they are doing an excellent and commendable job.

The approximate extent of variations in card web neps due to different factors was found to be as follows: variations due to stripping cycle: about 5 neps/grain, variations due to grinding cycle: about 5 neps/grain, variations due to fineness: about 6 neps/grain, variations in nep count between operators: about 2 neps/grain, variations due to card efficiency: about 18 neps/grain.

We want to know where we can best concentrate our attack on the problem of neps with greatest expectancy of reduction—in other words, with best return on investment spent for improving yarn appearance.

From past experience it has been observed that the gin puts in about half of the neps, and other operations, such as opening, cleaning, and picking, put in the other half of neps which are present in lap and represent the loading on the card for a total of about 30 to 35 neps per grain. This leaves a great burden on the card to remove such an enormous loading of

neps in lap. However, if properly adjusted and maintained according to best practice, the data show that even with such a tremendous loading the cards have performed a remarkable job in removing so many neps, the nep removal efficiency grade ranging from 80% to 91% in the process. Some of the individual cards rate in the Phi Beta Kappa class; others fail. Although the best standard practices are followed in a card room, proper action on those cards that fail will give a greater return on nep removal and produce a more uniformly clean cloth.

Another promising way to reduce neps outside the plant is in concentrating research to find an improved method of ginning in order to reduce loading of neps in the raw cotton [12]. One study by Williams and Towery indicated that roller ginning produced only about half as many neps as saw ginning in some varieties of American Upland cotton [17]. Mr. Wigington has suggested that damp cotton should not be ginned [16]. If neps caused by ginning could be reduced by half, this would be equivalent to raising the efficiency of all cards to the best one now in the line, or equivalent to cutting out all cleaning and picking operations. On the other hand, if all the cards were maintained at the level of the best one, neps would be reduced by half, but improvement in quality would hardly be sufficient to justify expense of such elaborate maintenance.

From the observations noted herein it is not concluded that the entire subject has been fully covered. It was only intended to present an elementary, yet somewhat revolutionary approach to stimulate further research in better processing and experiments in a better and improved method of ginning. If such research is accomplished more quickly, the purpose of this paper will have been achieved.

Summary

Valuable and useful information in determining the efficiency of old and new processing machinery may be obtained by the application of nep count techniques at all stages of processing. Results thus far indicate that control of neps can best be obtained by proper adjustment and maintenance of cards. It has been found in these studies that cards remove neps, whereas other processing steps increase neps. The nep count increases considerably in processing from seed cotton through gin, and from blending through

TABLE I. INFLUENCE OF PROCESSING ON NEP FORMATION

Seed cotton 2 neps/grain												
Process number	1		2		3		4		5		6	
	Neps*	Fineness†	Neps*	Fineness†	Neps*	Fineness†	Neps*	Fineness†	Neps*	Fineness†	Neps*	Fineness†
Cotton from bale	20	4.7	19	4.9	18	4.5	17	4.9	19	4.5	17	3.9
Hopper	21	4.1	—	—	19	4.8	—	—	20	4.5	19	4.1
Vertical opener	23	4.3	—	—	23	4.8	22	4.7	22	4.4	—	—
Lattice opener	27	4.2	22	4.4	25	4.5	24	4.9	24	4.4	—	—
Vertical opener	28	4.3	25	4.5	—	—	—	—	—	—	—	—
Vertical opener	—	—	27	4.4	—	—	—	—	—	—	—	—
Superior cleaner	30	4.6	—	—	28	4.3	27	4.6	27	4.4	21	4.1
Centrif.-air opener	—	—	—	—	—	—	—	—	—	—	25	4.3
Pickers:												
Blade beater	31	4.5	30	4.5	30	4.5	29	4.7	29	4.6	30	4.3
Blade beater	33	4.4	33	4.5	32	4.4	32	4.6	31	4.6	—	—
Kirschner beater	34	4.3	35	4.4	35	4.5	34	4.5	33	4.4	35	4.3
Cards:												
Card web	11	4.4	13	4.1	11	4.5	11	4.6	9	4.3	11	4.1
Highest card	29		29		19		25		24		20	
Lowest card	7		6		7		6		8		6	
Card sliver	12	4.4	13	4.1	11	4.5	11	4.6	9	4.3	13	4.1
Drawing sliver	14	4.6	14	4.5	12	4.6	13	4.7	14	4.4	15	4.0
Slubber roving	15	4.5	15	4.6	12	4.8	14	4.7	15	4.5	16	4.0
Yarn, comparative neps/yard	4.9	—	5.0	—	4.9	—	5.2	—	5.0	—	5.1	—
Nep removal efficiency of cards (%)	85		80		86		85		91		86	

* Neps—neps/grain (except in card web, neps/36 sq. in.).
† Fineness—μg./in.

picking operations, where it reaches a maximum, then decreases in carding depending on card adjustments, and again increases slightly through drawing operations. Improper processing causes more variations in nep count than differences in fiber properties, such as fineness. Variations in nep count due to fineness may be reduced to a minimum and necessity of frequent testing of bales eliminated if cotton is carefully purchased and properly blended. Further research could be most helpful if concentrated on improved ginning, carding, and other stages of processing.

Literature Cited

1. Ahmad, N., Research Work by the Technological Laboratory of the Indian Central Cotton Committee, *Indian Textile J.* **22**, 561–6 (1952).
2. Am. Soc. Testing Material D414–52 T, Tentative General Method of Testing Cotton Fiber, *Am. Soc. Testing Materials, Standards, Part 7*, 326–7 (1952).
3. Anon., What Makes Neps? *Am. Wool Cotton Reptr.* **65**, 17–8, 55 (August 9, 1951).
4. Anon., Relation of Mote Knives to Neps and Trash in Card Web, *Textile Inds.* **115**, 195, 197 (Sept. 1951).
5. Anon., Slow Card Grinding Reduces Neps, *Textile Inds.* **116**, 176 (Sept. 1952).
6. Bogdan, J. F., Review of Literature on Neps, *Textile Inds.* **114**, 98–103, 105, 107 (Jan. 1950).
7. Bogdan, J. F., and Feng, I. Y. T., Neps . . . And How to Control Them, *Textile World* **102**, 91–106 (May 1952).
8. Dougherty, J. E., Dance, L. H., and Martin, W. H., The Relation of Mill Processing Conditions to Yarn and Fabric Properties, *Textile Inds.* **116**, 111–26 (Oct. 1952).
9. Gulati, A. N., Causes of Neps in Indian Cotton Yarns, *Indian Textile J.* **60**, 65–9, 140–52 (Oct., Nov. 1949).
10. Harris, T. S., Nep Count Reduced by Opening and Picking Changes, *Textile Inds.* **115**, 99–100 (August 1951).
11. Marth, C. T., Arthur, H. E., and Berkley, E. E., Effect of Fiber Fineness on Nepping of Card Web., TEXTILE RESEARCH JOURNAL **22**, 561–6 (1952).
12. National Cotton Council of America, Cotton Fiber Properties, Spinning Efficiency and Fabric Quality as Affected by Ginning Practices (Mar. 31, 1952).
13. Orcutt, P. L., and Wakeham, H., A Method of Preparing Bulk Cottons for Nep Counting, TEXTILE RESEARCH JOURNAL **23**, 614–6 (1953).
14. Souther, R. H., *Cone Mills Laboratory Technical Bulletin No. 31* (Apr. 29, 1953).
15. Staff report, Air Jet Cleaning; More Trash Out and Fewer Neps, *Textile Inds.* **117**, 148–51 (Oct. 1952).
16. Wigington, J. T., The Effects of Ginning on the Spinning Quality of Cotton Fiber, *Cotton* **105**, 62–4 (July 1941).
17. Williams, S., and Towery, J., Saw-Ginned and Roller-Ginned Long-Staple American Upland Cotton: Spinning Quality, *Cotton* **109**, 110–2 (Apr. 1945).

A Method of Determining the Nep Content of Ginned Lint by Using Accessory Equipment with the Mechanical Fiber Blender

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A DESIRABLE FEATURE of any cotton is its relative freedom from neps, because they may be a source of trouble in manufacturing yarns and fabrics. The occurrence of neps in appreciable numbers detracts from the appearance of those products when they are to be dyed or printed because neps absorb dyes differently and appear as spots on the finished material. Neps are not found in unpicked cotton, but are formed when the fibers are manipulated at the harvesting, ginning, and processing stages. It is a recognized fact, however, that some cottons have a greater tendency toward the formation of neps than others.

Neps are fairly easy to count in specimens of card web taken during the processing of cotton on a commercial-type carding machine and when placed on

boards covered with black velvet. The use of this method of evaluating cotton samples with respect to neps is routine in connection with laboratory spinning tests. It is also used extensively in cotton-textile mills. The facilities and labor required to process samples through commercial picking and carding machines, however, prohibit the use of this method for routine tests, except in those cases in which the cotton is being processed for other purposes. Also, a minimum quantity of approximately 5 lbs. of cotton is required for such tests. In the case of mill tests, the cotton has already been processed through the card before the evaluation is made.

A method for evaluating raw cotton with respect to neps employing a small sample and relatively simple equipment would be a valuable addition to the field of cotton testing. Cotton laboratories could then provide the facilities for such evaluation without prohibitive expenditures, and samples moving in marketing channels could be tested before the bales are opened. The results of such tests would be more useful than those obtained after the bales are opened and the cotton is partially processed. However, various methods for counting neps in raw cotton which previously have been investigated in our laboratories have proved to be unsatisfactory either from the standpoint of the reproducibility of the results or from the standpoint of predicting spinning behavior. Furthermore, the time required for the tests has made them impractical.

Mechanical Fiber Blender

The method of making nep evaluations of raw cotton, as discussed in this paper, is based on the use of the mechanical fiber blender and accessory equipment. The blender is a compact portable machine powered by an electric motor. Essentially, it consists of a feed mechanism and a blending cylinder, as shown by the diagrammatic sketch in Figure 1. The feed is controlled by friction between a 1¼-in. fluted feed roll which turns at 6 r.p.m. and a spring-loaded feed plate. There are two settings on this machine —one for short-staple cottons and one for long-staple cottons as shown in Figure 1 (*A* and *B*). The blending cylinder is 12 in. in diameter and is covered with card stripper clothing or fillet. This cylinder turns at 84 r.p.m. to provide a surface speed ratio of feed roll to blending cylinder of approximately 1 to 135. These essential parts, which are 5 in. wide, are supported and driven by a suitable framework and drive mechanism.

Preparation of the specimen for blending comprises the extracting of random pinches of cotton from the sample to be tested and forming them by hand into a rough sliver or bat. This bat is supported by a feed apron (not shown in Figure 1). After being started by hand, the cotton is fed between the feed roll and feed plate. As the fibers are released by the feed mechanism, they are picked up by the blending cylinder, forming a thin layer of fibers. Consecutive thin layers are deposited one on top of the other as the cylinder revolves, thereby producing a blending action. When all of the cotton has been fed, the machine is stopped and the blended bat of cotton is removed by hand. Three passages through this machine are required to produce a good blend. Before a new sample is blended, the blending cylinder is stripped or cleaned with a stripping brush which is covered with card stripper clothing. The blender has a reversing switch for use when stripping the cylinder.

Accessory Equipment

The accessory equipment was designed to produce a thin web from a 3-g. sample of cotton which has been blended on the mechanical cotton fiber blender. It is a compact portable machine which is similar in principle to a commercial cotton-carding machine used in textile mills, but does not include the cleaning action provided by the card licker-in and grid bars. The speeds of the various parts are set up so that the web delivered and the rate of processing are equivalent to a 40-grain sliver produced on a 40-in. commercial cotton card at a rate of 9½ lbs./hr.

Essentially, the accessory equipment consists of a feed mechanism, a carding mechanism, and a doffing mechanism, as shown by the diagrammatic sketch in Figure 2. The feed mechanism is practically the

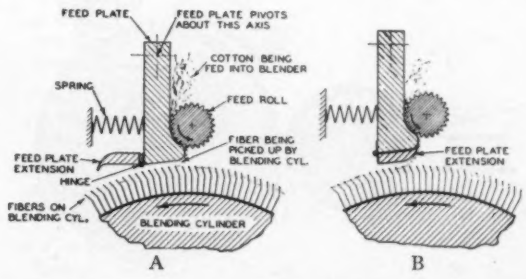

FIG. 1. *Diagrammatic sketch showing essential parts of mechanical fiber blender.* A—*Machine set for short-staple cotton.* B—*Machine set for long-staple cotton.*

same as the one used on the blender; it consists of feed apron, feed plate, and a fluted feed roll which turns at 5 r.p.m. The carding cylinder is $8\frac{1}{8}$ in. in diameter and is covered with card clothing or fillet. This cylinder turns at 290 r.p.m. to provide a surface speed ratio of feed roll to carding cylinder of approximately 1 to 410. The carding flat is a 2 in. × 4 in. block of wood which has the lower side rounded out and covered with card clothing or fillet to conform with the surface of the carding cylinder. The doffing cylinder is $4\frac{3}{4}$ in. in diameter and is also covered with card clothing or fillet. This cylinder turns at 83 r.p.m. to provide a surface speed ratio between carding cylinder and doffing cylinder of approximately 6.5 to 1. The doffing comb is the same as those used on commercial cotton cards, and oscillates at approximately 1,300 c.p.m. These essential parts, which are 5 in. wide, are supported and driven by a suitable framework and drive mechanism.

Settings between the various parts are used for all cottons as follows: feed plate to carding cylinder, .010 in.; carding flat to carding cylinder (back), $\frac{1}{16}$ in.; carding flat to carding cylinder (front), .010 in.; doffing cylinder to carding cylinder, .010 in.; and doffing comb to doffing cylinder, .022 in.

The 3-g. blended bat is laid out on a flat surface, and each edge is folded over slightly to provide an even edge and make the width approximately 4 in. Inasmuch as the length of the blended bat is the same as the circumference of the blending cylinder, this procedure provides a constant weight per unit area to be fed to the machine.

This bat is placed on the feed apron and started between the feed plate and feed roll by hand. As the fibers are released by the feed mechanism, they are picked up by the carding cylinder, forming a thin layer of fibers. These fibers are carded between the carding cylinder and the carding flat to untangle them and to obtain a uniform distribution on the cylinder. As the fibers continue to build up on the carding cylinder, the fibers on the surface are removed by and deposited on the doffing cylinder, which is turning at a slower surface speed. These fibers, in turn, are removed from the doffing cylinder by the doffing comb in the form of a thin web. This web is supported by hand, and specimens are placed on 4 in. × 9 in. boards covered with black velvet. The neps in the specimens of web on the boards are counted in making the nep evaluations. The carding cylinder, the carding flat, and the doffing cylinder are stripped or cleaned before a new sample is processed. Either a flat covered with card stripper clothing or a vacuum cleaner can be used for this purpose. The machine has a reversing switch for use in stripping the carding cylinder.

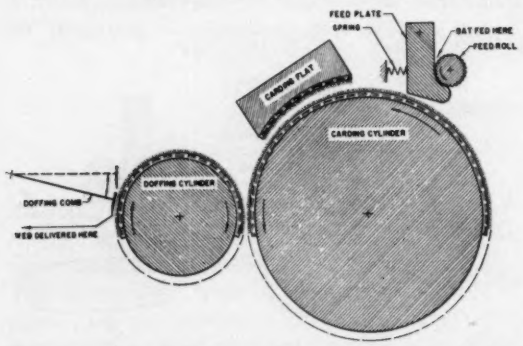

FIG. 2. *Diagrammatic sketch showing essential parts of accessory equipment for use with mechanical fiber blender for making nep tests.*

Procedure

There are usually pieces of seed-coat fragments, motes, leaf, and trash of various kinds, in addition to fiber tangles of various sizes in samples of raw cotton. All of these items appear as imperfections in a specimen of web prepared from the cotton. It is, therefore, a difficult problem in counting neps to decide which imperfection should be ignored. In our work, a nep is defined as a definite fiber tangle having a hard central knot or center and being sufficiently large to be detected easily. A sample of web is used as a standard in developing judgment of and agreement among technicians. The web used for this purpose has some neps labeled as being the smallest size to count and has others labeled as being too small to count. The neps labeled as too small to count are smaller than those classed as "A" in the nep standards of the American Society for Testing Materials. Our count, therefore, includes "A" neps and larger, as designated in the A.S.T.M. standard.

The following procedure has been adopted for routine tests for the evaluation of cotton samples with respect to neps by using accessory equipment with the mechanical fiber blender:

1. Condition sample for at least 4 hrs. in standard atmospheric conditions of 65% R.H. at 70°F.
2. Extract a representative 3-g. specimen by taking small pinches of fibers at random from a number of places in the sample.

3. Blend the 3-g. specimen on the mechanical blender three times, fold the resultant blended bat loosely for easy handling, and place in a box marked for identification.

4. Process the blended bat on the accessory equipment, extract ten 4 in. × 9 in. specimens of web as it is delivered, and place them in a storage rack.

5. Have each of two technicians count all of the neps in each of the ten specimens, using the nep standard as a reference in case of doubt.

6. Calculate the number of neps per 100 sq. in. of web from the average count of the two technicians.

Two technicians working together can organize this procedure so that there is little lost motion. The blending, preparation, and extraction of the web specimens, the counting of the neps, and the calculation of the results are four separate operations. By staggering these operations and alternating them between the technicians, a balance in the work load can be maintained. In this way, an average of four samples per hour can be tested.

Evaluation of Results

In evaluating this method, five replicate tests were made on each of six cottons to check the reproducibility of the results. Five of these cottons were upland types ranging from $\frac{15}{16}$ in. to $1\frac{3}{16}$ in. and one was a $1\frac{1}{2}$-in. type of American Egyptian. The thirty samples were assigned random numbers and were identified by these numbers only to eliminate bias between technicians in the testing operation.

An analysis of the results of these tests indicates that there was no significant difference in the results obtained by the two technicians (Table I). There is, however, a significant increase in the number of neps per board, which is progressive from board number 1 to board number 10. Board number 10 averages 38% more neps than board number 1. This increase in neps is attributed to the fact that the fillet becomes more loaded as the sample is processed. Inasmuch as ten boards were counted for each sample, however, the difference in the level of the results between the boards is not reflected in comparisons between cottons.

These results also indicate that nep data fit the Poisson distribution, in which the variance equals the average number in each replication ($\sigma^2 = \bar{X}$). The following estimated standard errors were calculated from this relationship for different levels of nep results when the neps in 360 sq. in. of web were counted:

Neps per 100 sq. in. of web	Standard error (σ)
10	±1.7
20	±2.4
30	±2.9
40	±3.3
50	±3.7
60	±4.1

Nep evaluations were also made on 498 upland cottons on which spinning test results were already available to check the significance of the results obtained. They were grown during the 1951 and 1952 seasons, and include a wide range of fiber properties, varieties, and growth conditions, which were grouped as follows: 34 short-staple samples carded at $12\frac{1}{2}$ lbs./hr.; 386 medium-staple samples carded at $9\frac{1}{2}$ lbs./hr.; and 78 long-staple samples carded at $6\frac{1}{2}$ lbs./hr. Results of simple correlation analyses for these three groups of cottons indicate that ginned lint evaluation of neps by this method explains more of the variance in carded yarn appearance than spinning

TABLE I. NEPS PER 100 SQ. IN. OF WEB PREPARED ON THE MECHANICAL FIBER BLENDER AND ACCESSORY EQUIPMENT FOR 5 REPLICATE TESTS ON EACH OF 6 COTTONS

Cotton and item*	Neps per 100 sq. in. of web† Technician 1	Technician 2	Average
Cotton No. 1 ($\frac{15}{16}$ in.)			
Average	20	21	21
Range	7	7	7
Cotton No. 2 (1 in.)			
Average	18	17	17
Range	9	6	8
Cotton No. 3 ($1\frac{1}{32}$ in.)			
Average	29	28	28
Range	5	8	6
Cotton No. 4 ($1\frac{1}{8}$ in.)			
Average	60	63	61
Range	21	13	17
Cotton No. 5 ($1\frac{3}{16}$ in.)			
Average	25	27	26
Range	8	5	7
Cotton No. 6 ($1\frac{1}{4}$ in.)			
Average	28	27	27
Range	3	5	4
All 6 cottons			
Average	30	31	30
Range	8	7	7

* Five replicate tests were made on each cotton.
† Neps were counted in 360 sq. in. of web for each test.

TABLE II. RESULTS OF SIMPLE CORRELATION ANALYSES OF CARDED YARN APPEARANCE WITH NEP TEST DATA FOR 3 GROUPS OF COTTONS, CROPS OF 1951 AND 1952

Statistical items and groups of cotton*	Samples	Results of simple correlation analyses of carded yarn appearance† with: Neps in card web‡	Neps in accessory web‡
Coeff. of correlation			
Short staple	34	−0.433 ± 0.141	−0.590 ± 0.114
Medium staple	386	−.578 ± .034	−.722 ± .024
Long staple	78	−.755 ± .049	−.788 ± .043
Coeff. of determination			
Short staple	34	0.187	0.348
Medium staple	386	.334	.521
Long staple	78	.570	.620
Standard error of estimate			
Short staple	34	±6.37	±5.71
Medium staple	386	±8.31	±7.05
Long staple	78	±6.35	±5.97

* Carding rates of 12½, 9½, and 6½ lbs./hr. were used for short-, medium-, and long-staple cottons, respectively.

† Average yarn appearance index for two yarn numbers, in which 20 index points equal one A.S.T.M. yarn appearance grade, was used in the analyses.

‡ Neps per 100 sq. in. of web was used in the analyses.

test evaluation of neps in card web, as shown in Table II.

Ginned lint evaluations of neps explain 35% of the variance in carded yarn appearance as compared with 19% explained by spinning test evaluation of neps in card web for short-staple cottons, 52% as compared with 33% for medium-staple cottons, and 62% as compared with 57% for long-staple cottons. Other statistical values show this same trend of greater significance for ginned lint evaluations as compared with card web evaluation. The higher correlation values, however, may be attributable to some extent to the conditions under which the evaluations were made. Only one machine and the same two technicians were used in making the ginned lint evaluations over a period of several months, whereas two cards and several technicians were used in making the card web evaluations over a period of approximately 1½ years.

Status of Method

The results presented in this paper were obtained by using an improvised laboratory model of the accessory equipment. This model has been in operation in the Washington laboratory of the Cotton Division of the Agricultural Marketing Service for more than a year, and has been used routinely in the testing program for the 1953 crop. The design and construction of a finished model are in progress and should be completed within the next few months. It is planned to issue a publication when the finished model has been tested at which time working drawings will be available.

Conclusion

In conclusion, we believe that the method presented here for evaluating the ginned lint with respect to neps is practical. Two technicians can test an average of four samples an hour by this method, using relatively simple equipment and a small sample of cotton. The results of such tests are also slightly more significant in explaining spinning behavior than the results of neps in card web employing commercial-type, textile-processing machines.

Effect of Cotton Fiber Strength on Single Yarn Properties and on Processing Behavior*

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Introduction

Fiber length, fineness, and strength are the properties which contribute the most to yarn strength. Yarn strength is considered to be the principal criterion of yarn quality. Recently, breeders have developed cotton varieties having fiber strengths which average from 25% to 50% above normal. These new cottons of average length but with a high fiber strength will find a ready market if they can be processed efficiently and satisfactorily.

It is the purpose of this study to determine the effect of the strength of the fiber upon the strength of the yarn. At a previous Cotton Research Clinic we reported on the effect of fineness of cotton fibers upon yarn strength, and the findings of this study were published in the October, 1951, issue of the TEXTILE RESEARCH JOURNAL. At some later date, we hope to have an opportunity of reporting on a similar study of the effect of fiber length on yarn properties. We plan to set up tables showing the values of the various fiber properties as they influence yarn properties, and from these tables we hope to derive a formula which will form a basis for predicting yarn strength for any cotton whose fiber properties are known. Such a prediction formula would be useful to cotton breeders in guiding them in their breeding work; it would likewise be useful to manufacturers in their selection of the cotton to be purchased for specific uses.

Most investigators working statistically on the correlation of fiber properties with yarn quality have agreed that fiber strength contributes materially to single yarn strength. Webb and Richardson [4] in their statistical study in 1951 concluded that fiber strength is less important than fineness in cottons $\frac{7}{8}$ in. to $\frac{31}{32}$ in. in length, but more important for cottons 1 in. to $1\frac{3}{32}$ in. in length.

Most statistical approaches have been confined to an evaluation of the effect of fiber strength on maximum single yarn skein strength, without attempting to evaluate the effect of fiber strength on the properties of single yarns of varying twists or its effect on product uniformity, on processing techniques, or on fabric qualities.

With the idea of obtaining a better understanding of the effect of fiber strength on the properties of single and two-ply yarns of varying twists and on fabric quality, an investigation of the fiber strength-yarn-fabric relationship has been undertaken at the Southern Regional Research Laboratory in cooperation with the Cotton and Other Fiber Crops and Diseases Section, Field Crops Research Branch. The present discussion of the effect of fiber strength on processing techniques and on the important physical properties of single yarns of varying twists is the first of a series of such investigations.

Materials and Methods

Samples

Two cottons with fiber strength of 96,000 and 80,000 p.s.i. and having other important fiber properties approximately equal were selected. These cottons were identified as Hopi Acala 50 (high strength) and variety *A* (medium strength). Figure 1 shows photomicrographs of these two cottons. Both cottons are fairly uniform and circular in cross section, with

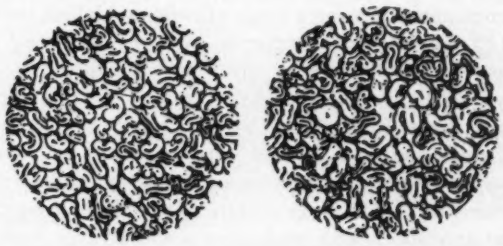

FIG. 1. *Photomicrographs of two cottons differing in fiber strength.* Left—*Hopi Acala 50; Pressley index, 9.2.* Right—*Variety A; Pressley index, 7.6.*

* Presented by John J. Brown at the 1954 Cotton Research Clinic, Pinehurst, N. C.

† One of the laboratories of the Southern Utilization Research Branch, Agricultural Research Service, United States Department of Agriculture.

TABLE I
Summary of Fiber Properties

Fiber Property	Hopi Acala 50	Variety A
Grade		
Classer	SLM+	SLM+
Length		
Classer (in.)	1-3/32	1-3/32
Suter Webb		
UQ (in.)	1.24	1.23
Mean (in.)	1.06	1.01
C.V. (%)	26.00	31.00
Fibrograph		
UHM (in.)	1.11	1.06
Mean (in.)	0.91	0.83
UR (%)	82.00	79.00
Fineness		
Suter Webb (µg./in.)	3.90	4.10
Micronaire (µg./in.)	4.60	4.50
Arealometer		
Specific Area (mm^2/mm^3)	427.00	424.00
Perimeter (µ)	46.45	46.21
Cell Wall Thickness (µ)	2.92	2.95
Immaturity Ratio	1.58	1.56
Strength		
Pressley Index	9.20	7.60
Maturity (%)		
Sodium Hydroxide	93.00	90.00

TABLE II
Effect of Fiber Strength on Waste, Neps and Twists Required in Selected Hank Rovings to Obtain Efficient Processing

Manufacturing Details	Hopi Acala 50	Variety A
Waste	Percent	Percent
Opening & Breaker Picker 1/	1.34	1.65
Finisher Picker 1/	0.35	0.46
Card 1/	5.55	5.90
Total 2/	7.15	7.89
Neps	100 sq. in. / 35	100 sq. in. / 35
Hank Roving	T.P.I.	T.P.I.
1.3	1.25	1.14
2.6	1.82	1.73
4.0	2.29	2.21
6.0	2.96	2.84

1/ Based on net weight fed at each process.
2/ Based on weight of raw cotton fed.

most fibers having well-developed cell-wall thicknesses. Table I gives the fiber properties of these two cottons.

Processing and Testing Procedures

The cottons were processed alike on conventional processing equipment into 12/1, 22/1, 36/1, and 50/1 yarn numbers, using a range of twist multipliers from 2.75 to 6.75 in increments of one. Neps were counted; uniformity of sliver was measured by a converted Saco-Lowell Sliver Tester * [3]; rovings and yarns were tested with a Uster Uniformity Tester; and yarn grades were evaluated by comparisons with yarn appearance standards, in accordance with A.S.T.M. procedure [1]. Skein strength determinations were made on a pendulum-type tester

* Mention of trade names does not imply their endorsement by the Department of Agriculture over similar products not mentioned.

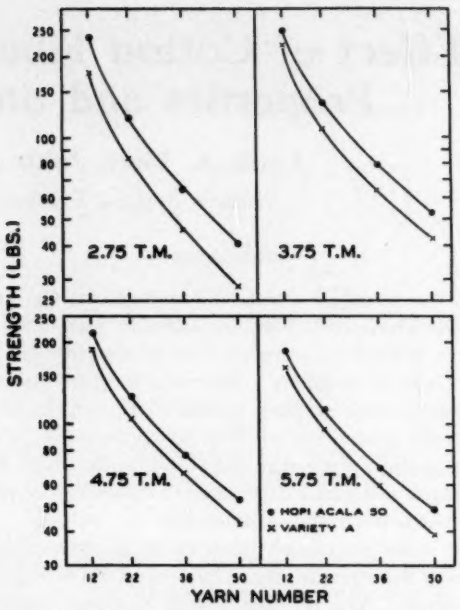

FIG. 2. *Effect of yarn number and twist on the skein strength of yarns spun from cottons differing in strength.*

of 150–300 lbs. capacity. Single strand strength and elongation measurements were made on an inclined-plane tester of 250 to 2,000 g. capacity.

Experimental Results and Discussion

Skein and single strand strength data were plotted on semilogarithmic paper for the purpose of comparing proportional rates of change in yarn strength for a given yarn number spun from the two cottons. Plotting strength on rectilinear paper, on the other hand, would have shown only the absolute numerical difference.

Processing Behavior

Table II shows the effect of fiber strength on processing behavior when evaluated in terms of waste percentage, nep formation, and turns per inch required to obtain good drafting.

Waste percentages were slightly smaller for the Hopi Acala, but this slight difference is not considered significant. The nep count per 100 sq. in. of card web was the same. This indicates that the strength of the fiber has little or no effect on processing behavior at the opening, picking, and carding stages. Therefore, from these observations and those

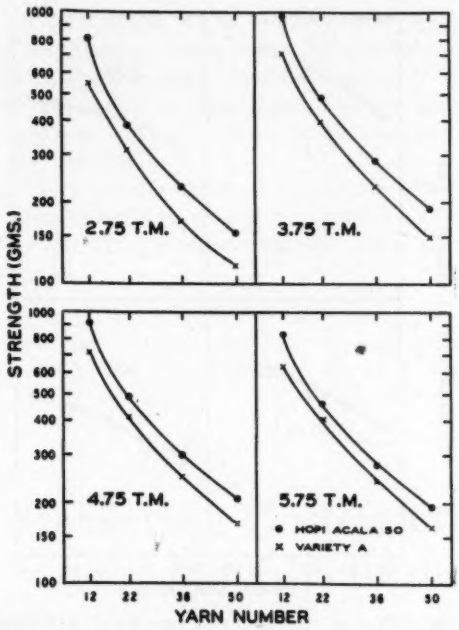

FIG. 3. *Effect of yarn number and twist on the single strand strength of yarns spun from cottons differing in strength.*

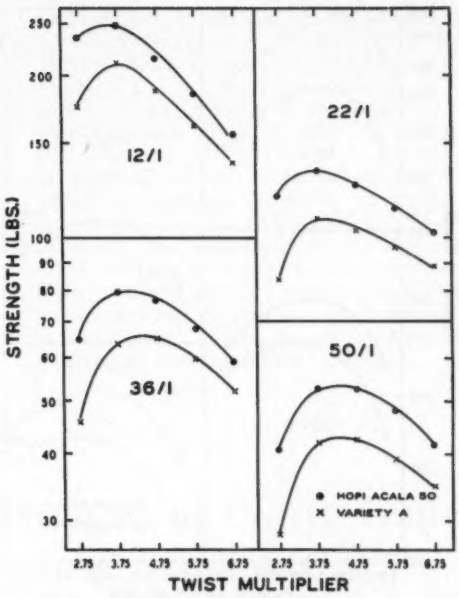

FIG. 4. *Effect of fiber strength on the skein strength of single yarns of varying twist.*

of Bogdan and Feng [2], such properties as length, fineness, and maturity, collectively, probably are the principle contributors to cleaning efficiency and nep formation. From a practical viewpoint, strength of the cotton fiber does not significantly influence the amount of twist required to obtain good drafting qualities since the principal determinant of twist in roving is interfiber friction rather than fiber strength. Frictional characteristics are influenced mainly by fiber length and fineness.

Yarn Strength

The relationship between both the skein and single strand strengths over the range of yarn numbers spun for each twist multiplier was used to evaluate the spinning behavior of these two cottons. Yarn number *versus* skein strength for a series of twist multipliers is shown in Figure 2. For a given twist multiplier, the percentage yarn strength loss per unit increase in yarn number is about the same for the two cottons, but this loss decreases with increases in yarn number. Based on the over-all range of yarn numbers (12/1 to 50/1), these losses decrease with increase in twist multiplier, averaging for the two cottons 83.3% for 2.75 T.M., 79.3% for 3.75 T.M., 76.3% for 4.75 T.M., and 75.0% for 5.75 T.M. Figure 3 shows the single strand strength *versus* yarn number for the same twist multipliers. These single strand curves are similar to the skein strength curves shown in Figure 2.

Figure 4 shows the effect that fiber strength has on skein strength for the 12/1, 22/1, 36/1, and 50/1 yarn numbers. The twist-strength curves for the two cottons are similar. The high-strength cotton spun into stronger yarns for all yarn numbers and twists. At low single twist (2.75 T.M.) yarns spun from the high-strength cotton averaged from 35% to 40% stronger than yarns from the weaker cotton. As single yarn twist increases, the difference in yarn strength becomes progressively less, until at the high twist (5.75 T.M.) the yarn spun from the high-strength cotton averaged only 12% to 20% stronger than yarns from the weaker cotton. Maximum strength for yarns spun from the two cottons was obtained with approximately the same twist multiplier for any given yarn number. Generally, the twist required for maximum strength increased slightly with increases in yarn number.

Figure 5 shows twist-strength curves based on the single strand strengths of different yarn numbers using different twist multipliers. These curves re-

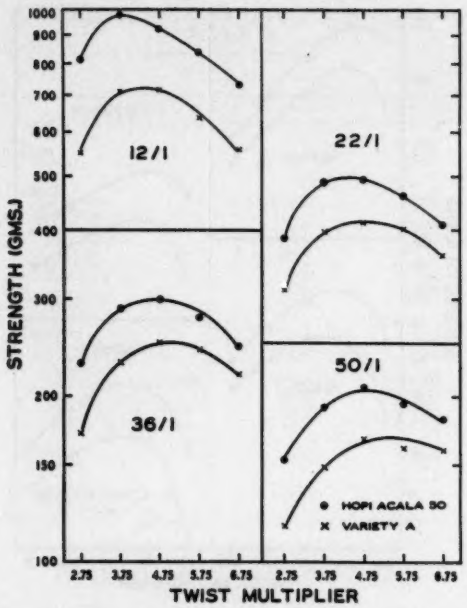

FIG. 5. *Effect of fiber strength on the single strand strength of single yarns of varying twist.*

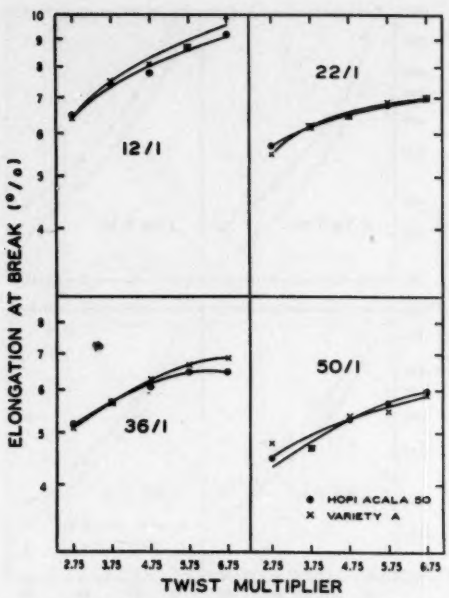

FIG. 6. *Effect of fiber strength, yarn twist, and number on the elongation of single yarns.*

TABLE III

Effect of Fiber Strength on the Uniformity of Slivers, Rovings, and Yarns and on the Appearance of Yarns

Product	Quality Evaluation			
	Hopi Acala 50		Variety A	
Card Sliver[1]	% C.V. 2.74		% C.V. 2.75	
Drawing Sliver[1]	4.24		4.08	
Hank Roving[2]	% M.D.	% Range	% M.D.	% Range
1.3	4.98	25.2	5.09	27.7
2.6	6.36	34.6	6.52	35.6
4.0	7.10	39.2	7.81	45.3
6.0	8.87	51.5	9.74	56.7
Yarn Number[2]				
12/1	10.48	52.9	10.85	58.1
22/1	12.69	70.1	13.22	75.0
36/1	14.45	85.2	15.32	86.4
50/1	15.59	90.6	16.63	97.8
Yarn Number[3]	Grade		Grade	
12/1	A		A	
22/1	A-		A-	
36/1	A-		B+	
50/1	A-		B+	

1/ Saco-Lowell Sliver Tester
2/ Uster Evenness Tester
3/ ASTM Appearance Standards

semble those based on skein strength values (Figure 4) and lead to the same conclusions, the only difference being that maximum strength occurs at a higher T.M. This difference is not unexpected, since it is well known that the values obtained by the two test methods differ in this respect.

Figure 6 shows the twist-elongation curves for the two cottons. These two cottons spun into yarns of approximately equal elongation.

Uniformity and Appearance

The uniformity of slivers, rovings, and yarns, and the appearance of yarns produced from the two cottons of widely different strengths are shown in Table III. Uniformity values of these textile products did not differ significantly from one cotton to another. It is evident that fiber strength does not affect product uniformity at these stages of processing. In the case of yarn appearance, the finer yarn numbers spun from the high-strength cotton apparently spun into yarns of slightly better grade than those spun from the other cotton. However, due to the visual method of evaluation and the small differences noted in grade, it does not appear that fiber strength significantly affects yarn grade (appearance) over the range of yarn numbers studied.

Conclusions

Within the experimental conditions of this investigation, it is concluded that:

1. The strength of the fiber has little or no effect on processing efficiency through spinning.

2. High-strength cotton produces stronger yarns than low-strength cottons for any given yarn number or twist, a well-known general relationship.

3. The amount of twist required to obtain maximum strength in single cotton yarns is not affected by fiber strength.

4. Fiber strength does not significantly affect the uniformity of slivers, rovings, or single yarns.

5. Fiber strength does not significantly affect yarn elongation.

Literature Cited

1. Am. Soc. Testing Materials, Committee D-13, "A.S.T.M. Standards on Textile Materials (with Related Information)," Philadelphia, 1952 (A.S.T.M. Designations: D 180–52 T, D 414–52 T, D 1441–52 T, and D 1442–52 T, and Appendix X).
2. Bogdan, J. F., and Feng, I. Y. T., Neps . . . and How To Control Them, *Textile World* **102**, 91–106 (1952).
3. Rusca, R. A., Conversion of the Saco-Lowell Sliver Tester to Electrical Recording, TEXTILE RESEARCH JOURNAL **20**, 780–6 (1950).
4. Webb, R. W., and Richardson, H. B., "Relation of Count-Strength Product of Long-Draft Processed Yarn to Six Elements of Raw Cotton Quality and Yarn Size," Production and Marketing Administration, U. S. Department of Agriculture, 1950, 61 pp. (mimeographed report).

Measuring Cotton Fiber Strength at Finite Gage Lengths in the Breeding Program

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THE IMPROVEMENT of fiber strength is an important part of our cotton breeding programs. The evaluation of fiber strength along with that of length and that of fineness are standard tests in screening large populations in the quest for better cottons. In a typical breeding cycle, thousands of plants are tested each year for the best combinations of fiber properties, disease-resistance, and agronomic properties. These populations may come from a cross or they may come from a field that is not genetically pure. The first evaluation of fiber quality and agronomic properties is essentially a preliminary screening to find the best plants. Seeds from the most promising selections are planted the following year, and from this crop further tests are run and more rigorous selections are made. This may be repeated several years, during which time the seed supply of the final selections have been multiplied for release. As the seed supply is increased, it is possible to run more refined tests, such as yield tests at various locations and spinning tests. For the most part, spinning trials are made only on strains that have been shown to have acceptable agronomic and fiber properties. It is a fair approximation to say that out of 500 original selections that have been tested for fiber properties, with fewer numbers reselected and retested in subsequent years, only one will ever reach a spinning test. Therefore, from the breeding standpoint, the tests for fiber properties are the important tests. In the case of fiber strength, all the fiber screening is done with the Pressley breaker, which has been used for the past 14 years.

In addition to this general program, there have been other projects with the specific objective of improving fiber strength. Wild cottons having extremely high strength, such as the Triple Hybrids and Hopis, have been crossed with commercial types, and selections have been made to obtain the best possible combinations. In this work, as in our regular breeding projects, the Pressley breaker has been used as the basis for all preliminary screening. Serious difficulties have been encountered in attempts to combine outstanding strengths and the yields of Upland cottons. Some of the difficulties are associated with the problem of the transference of characteristics from one species to another, but a number of agronomists have come to the conclusion that there is an inverse correlation between strength and yield (*i.e.*, the higher

the strength, the lower the yield). This has been discussed at length in the meetings of the Spinner-Breeder Conferences.

It is recognized that fiber strength is a complex property, and any one measure, such as that made with the Pressley breaker, has arbitrary limitations At previous meetings of the Cotton Clinic, and particularly at last year's meeting, evidence was presented which showed that the limitations of the Pressley breaker are such that values obtained with this instrument do not give the best measure of the contribution of fiber strength to yarn strength.

When strength tests are made with the Pressley tester, the fibers are broken with no distance between the two holding jaws, or at "zero gage length." Three years ago, at the Cotton Clinic, Phillips showed that the tensile strength of Upland cottons is about 50% less when tested at 5-mm. gage length than at zero gage length, but fiber strength at 5-mm. gage length was better correlated with yarn strength. The work of Phillips was done by mounting the jaws from a Pressley tester on a Scott IP-4 machine. Since that time, two new fiber strength testers have been developed in which it is possible to use variable gage lengths: (*1*) the Clemson flat bundle tester, by Brown, and (*2*) the Stelometer, by Hertel. Hertel and Brown both presented data at the Cotton Clinic last year, confirming the results of Phillips. Both used samples coming from our annual variety studies from the crop of 1951. From the crop of 1952, each cotton that was spun was tested on the Pressley breaker at zero gage length and also with the Stelometer at $\frac{1}{8}$-in. gage length. Twelve breaks were run from each cotton, both from the ginned lint and the second drawing sliver. A total of 148 cottons spun into carded yarns showed a correlation coefficient between the skein strength of 22's and tenacity at $\frac{1}{8}$-in. gage length of 0.81; between 22's and Pressley index on the same cottons there was a correlation coefficient of 0.54. In these cases, fiber strength was determined on the ginned lint. When fiber strength was determined on the second drawing sliver, there was a correlation coefficient of 0.83 between the skein strength of 22's and tenacity at $\frac{1}{8}$-in. gage length. Averaging the 24 breaks, on ginned lint and second drawing sliver, the correlation coefficient between the tenacity at $\frac{1}{8}$-in. gage length and skein strength of 22's was 0.92. Thus, it is possible with this one fiber measurement to account for 84% of the variability in skein strength. Similar results were obtained on the combed yarn series, in which Uplands, Hopi Acala, Triple Hybrids, and long-staple Barbadenses were combined into one analysis. The correlation coefficient for 79 cottons between the skein strength of 36's combed yarns and tenacity at $\frac{1}{8}$-in. gage length was 0.93.

It is obvious that a measure of strength such as tenacity at $\frac{1}{8}$-in. gage length should be incorporated as a standard test in our breeding program. It is necessary to understand what this test means, how it might affect our breeding program, and how it might subsequently affect the cotton reaching the mills.

In analyzing bundle strength at last year's Cotton Clinic, Wakeham pointed out that as the length of fiber between the bundle clamps increases, strength decreases because of the weak places along the length of the fibers. Bundle strength is also reduced by the variability of the fibers within the bundles in breaking elongation. It is further reduced by variable fiber crimp. Thus, a number of factors are responsible for the reduction in strength at $\frac{1}{8}$-in. gage length. These factors which are responsible for the reduction in fiber strength with increasing gage can be attributed to structural heterogeneties along the

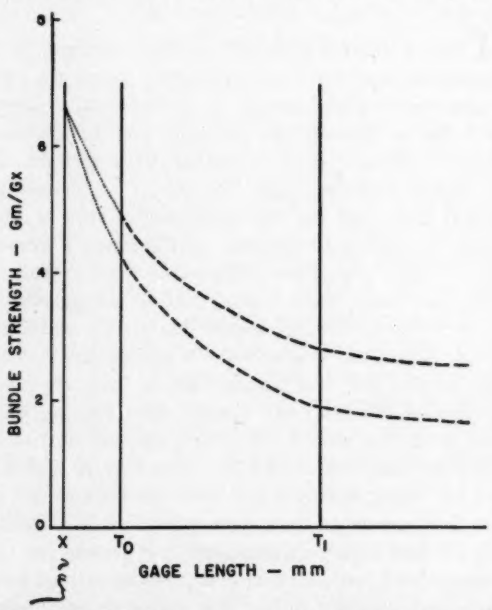

FIG. 1. *The loss in bundle strength with increasing gage length. The* T_0 *zero gage length is not a true zero, but must be projected. It is postulated that the x-ray angle gives the true zero (or closely approximates it).*

length of the fiber and variability in the structural heterogeneties among the fibers in a bundle. Now the question arises: What structural features are responsible for the level of strength of the fiber bundle before the structural heterogeneties reduce that strength? This point was not discussed last year, but, considering the structure of cellulose and all we know of the structure of the cotton fiber, it is apparent that the overwhelming factor contributing to the initial strength is the spiral structure of the cellulose chains along the fiber axis, which is measured by the x-ray angle. The so-called "zero gage length" is not a true zero.

Now let us combine results which Berkley published in 1948 with results from the $\frac{1}{8}$-in. gage length, using a standard Upland and an American-Egyptian as contrasting types. Let us assume that both cottons have an x-ray angle of 30° (Figure 1). Berkley showed that an American-Egyptian cotton with an angle of 30° has an average Pressley index of 9.2 or a tenacity at zero gage length of 4.92 g./gx., whereas a commercial Upland of 30° has an average Pressley index of 7.8 or tenacity at zero gage length of 4.17 g./gx. At $\frac{1}{8}$-in. gage length the American-Egyptian cotton has a bundle strength of 2.80 g./gx., whereas the Upland has a value of 1.96. The yarn strength of 22's carded for the American-Egyptians will be approximately 175, and that for the Upland 122.

This curve shows that fiber strength which is best calculated with yarn strength can be separated into two measurable components: (*1*) the height of the curve at the point of origin or the x-ray angle, and (*2*) the slope of the curve at some arbitrary point once it has flattened. (In the Stelometer this is taken at $\frac{1}{8}$-in. gage length, which Hertel calls T_1.) The slope of the curve is influenced by several fiber properties which can be explained by one structural feature—uniformity along the length of the fiber. Previous papers have emphasized the loss in fiber strength with increasing gage length. From a breeding angle, the important point to emphasize is the variability in the rate of loss. In the past, this factor has not been measured. Therefore, it is interesting to see how much the rate of loss varies in our breeding material. This has been done by plotting the x-ray angle against the bundle strength at $\frac{1}{8}$-in. gage length (or T_1). If the rate of loss in strength were the same for all cottons, then the x-ray angle

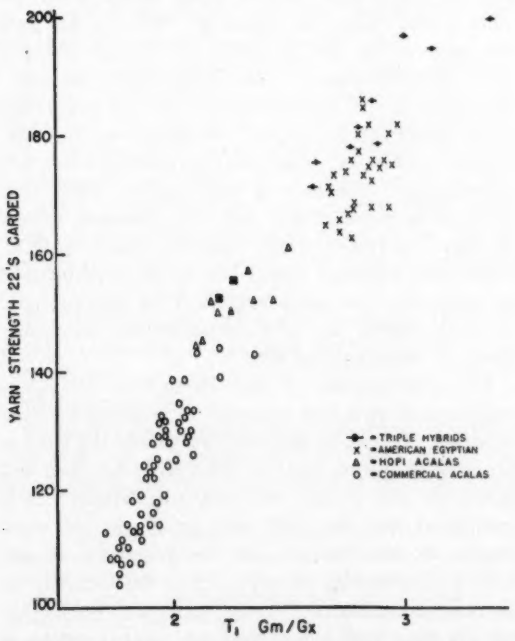

FIG. 2. *Relation of bundle strength at $\frac{1}{8}$-in. gage length to the strength of carded 22's in the widest range of cottons in our breeding blocks.*

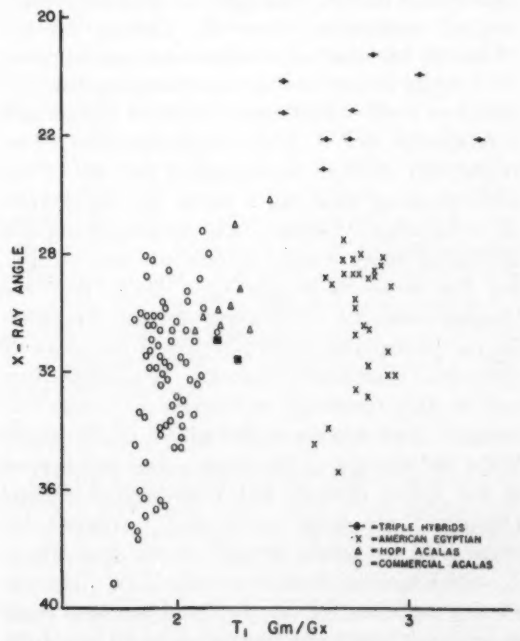

FIG. 3. *Relation of x-ray angle to* T_1 *(bundle strength at $\frac{1}{8}$-in. gage length).*

would be perfectly correlated, within the limits of experimental error, with tenacity at $\frac{1}{8}$-in. gage length, and there should be a straight-line relationship. This is far from the case, as can be seen from Figure 3, in which a selected group of cottons representing the widest genetic variability have been plotted. (Upland cottons not grown under irrigation have been omitted from this chart because of limitations of numbers.) There are four types of cottons plotted in Figure 3: (*a*) Uplands grown under irrigation in the southwest, (*b*) Barbadense long staples, (*c*) Triple Hybrids from Raleigh, and (*d*) Hopi Acala types grown under irrigation. The first striking feature is that the American-Egyptian and other Barbadense cottons stand out completely from every other group in having high T_1 with a relatively low x-ray angle. Among 227 cottons tested last year, not one of the Barbadense long staple overlapped with any other cottons in this respect. Secondly, in our efforts to breed cotton with outstanding strength in the case of the Hopi Acalas and the Triple Hybrids, we have been mainly concerned with a decrease in the x-ray angle, although there is considerable variability in the loss with increased gage length in the case of some of the Triple Hybrids. It should be remembered that the main basis for selection of high-strength cottons has been the Pressley breaker. Therefore, one must come to the conclusion that using the Pressley breaker as a tool for testing high-strength selections results chiefly in a decreased x-ray angle.

It appears that it might be advantageous to increase fiber strength by decreasing the rate of loss with increasing gage length rather than by decreasing x-ray angle. George Buck has pointed out that decreasing the x-ray angle not only increases strength, but also decreases elongation to break, flex, and abrasion-resistance. Increasing strength by selecting for greater fiber uniformity should not adversely affect these other fiber properties. In addition, there may be other advantages to selecting for greater uniformity. Last summer at Raleigh, N. C., Dr. Philip Miller had segregating lines from a cross between one of the Triple Hybrids and a commercial Upland (Empire). He found an inverse correlation between yield and bundle strength at zero gage length, T_0, with a correlation coefficient of -0.59. The correlation coefficient between yield and bundle strength at $\frac{1}{8}$-in. gage length was less than or equal to -0.29. These was no correlation between the rate of loss with increasing gage length and yield. These results shall be rechecked.

To those of us working in this field for a number of years, the simple correlation between the bundle strength at $\frac{1}{8}$-in. gage length and yarn strength is extremely impressive. It is possible to account for as much of the variability in skein strength with this simple correlation as it is with the involved multiple correlations previously used. Furthermore, it is not necessary to stratify our data in obtaining such a correlation. It is recognized that something new is being measured, but at the same time one must ask the question: What are the contributions of length and fineness to skein strength if bundle strength explains so much? Let us consider the question of length. The relationship between U.H.M. length and yarn strength is quite high, but in our breeding studies it has also been found to be extremely variable, depending upon the season and the genetic stocks used. The question that faces us at present is this: How much is length correlated with the rate of strength loss with increasing gage length? Or, to put it another way: How much is length responsible for the extra-long staples being apart from the other types shown in Figure 2? We do not have the answer, but we do know that length alone is not responsible since Upland long staples are essentially part of an "Upland series" and are not similar to the American-Egyptians. Furthermore, the relationship within the American-Egyptians is extremely encouraging. We have a new variety, Pima S-1, ready to be released this year. In this new variety we have increased yield, and decreased U.H.M. length and Pressley index, but we have maintained the strength at $\frac{1}{8}$-in. gage length and the yarn strength. In other words, we have increased the uniformity along the length of the fiber.

The determination of fiber strength at $\frac{1}{8}$-in. gage length opens up a new approach in breeding for fiber strength. It will be necessary to survey the field of our genetic stocks, and we shall have to place emphasis on new crosses and new populations. It is anticipated that we shall meet pitfalls as the work progresses, but there is also the possibility of our making outstanding progress. For this reason, we are ready to retire the Pressley breaker in our breeding program and concentrate on measurements at finite gage lengths.

Structure and Properties of Cotton and Synthetic Singles Yarn

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Introduction

The aim of this paper is to present simple ways for the mill man or yarn designer to handle everyday problems connected with spinning singles yarn. For example, the twist multiplier for maximum strength * or for minimum ends-down may be wanted. Or in spinning a different cotton count it may be desirable to estimate the new values of yarn properties which result—strength, evenness, etc. Similarly, if fiber denier or fiber length is changed, it is desirable to be able to estimate how the properties will be affected. Furthermore, even when the yarn designer knows what properties he wants and what structure will provide these properties, he may, without adequate knowledge, come up with a yarn which is unspinnable or for which processing costs are prohibitive. The emphasis throughout is on practical results.

The agreement to be expected between estimates made by the mathematical formulas developed and experimental results is shown on the numerous plots by the divergence of the points from the line on which the computations are based. Limitations of the data on which conclusions are reached have been made clear. The approach is empirical, which has the advantage that experimental figures must be employed and shown at every step.

For those engaged in research on singles yarn, this paper has the merit of serving to expose gaps in existing knowledge which must be filled if we are to master yarn design.

Following some general topics, the paper is divided into Part I on synthetics and Part II on cotton. For those who heard the author's talk at the Cotton Research Clinic, it is pointed out that a method has been found for taking fiber length into account by means of the fiber-ends function, thereby rounding out the treatment of the elements of gross structure—fiber length, fiber denier, cotton count, and twist. The fiber-ends function has also provided a simpler method for estimating spinning limits than that presented at the Pinehurst meeting.

Ply yarns will be treated in a third part of the paper, to be published at a later date. Combination multipliers have been developed which express in one figure singles and ply twists, and provide for the selection of twists to use when specific properties are wanted.

Structure of Staple Singles Yarn

The basic information we are seeking is concerned with the question of how yarn properties are related to structure, since structure is within the control of the designer (weight of yarn—*i.e.*, cotton count—is governed by end-product requirements).

In a sense, the properties of yarns as they occur in fabrics are of first importance, since fabrics are the end-products in which yarns appear. It has been pointed out [7] that yarn properties as they contribute to fabric properties can be ascertained most simply and accurately from tests on fabrics. It is in processing that the properties of singles yarns are of greatest interest, since it is in processing up through the stages of weaving or knitting that yarn properties determine costs.

Commercially Useful Properties of Singles Yarns

The most important of these properties are: yarn strength (preferably impact rather than static); yarn irregularity; and ends-down in spinning. We need to know how these properties depend upon gross structure, the elements of which are twist, fiber fineness, fiber length, and cotton count of the yarn; we also need to know the mathematical functions for handling these properties.

* The phrase "at maximum strength" used throughout the paper may lead to the mistaken impression that the property in mind is exclusively strength. For the comparing of properties a "bench mark" is needed, and the condition which provides maximum strength has proved satisfactory for the purpose. As so many writers have stressed, yarns should be designed for the combination of properties required for their intended end-use, and for strength only when strength is a functional property.

Elements of Structure

There are both gross and fine structures of yarns. Since we know little that is useful about the latter (though we should know more in time), the present study is limited to gross structure.

In the past, the only recognized element of yarn structure which was practically utilized was twist. The twist multiplier, which mathematically generalized twist, has been a valuable implement in everyday work. The major contribution of this paper is the discovery of another element of gross structure of singles yarn and the development of two new mathematical functions for practical use.

The newly recognized element of structure is the size of the fibers in relation to the size of the yarn. A fine yarn spun of coarse fibers has a different structure from that of the same fine yarn spun of fine fibers. A coarse yarn spun of coarse fibers may have the same structure in this respect as the fine yarn spun of fine fibers, and thus they will have properties in common. This element of structure may be called "yarn discreteness," and its mathematical generalization is the "subdivision ratio" described later in this paper.

Another element of structure, well recognized, which must be taken into consideration if the relation of yarn properties to structure is to be complete, is fiber length. This element has been included in a second simply usable mathematical function, the "fiber-ends function," which is also described later in this paper.

Twist

Twist is a dominating element of structure of yarns, and for designing singles yarn it would be valuable to have generalizations on the twist multipliers which provide the wanted yarn properties. Specifically, for the design of singles yarn we would like to know the twist multiplier for maximum strength, the twist multiplier for minimum variability, and the twist multiplier for minimum ends-down.

Strength plotted against singles twist multiplier gives an inverted U-shape curve, and the other two properties also show U-shape curves. The property values fall off or increase on both sides of the twist at the point where the slopes of the arms of the U reverse. For properties which show U-type curves, it is meaningless to make any such general statement as "the strength of 20s viscose yarn is so many pounds." If not at the unique (or reversal) point, there are two twist multipliers, one for one branch and another for the other branch, which provide the same tenacity. The tenacity is the same, but all other yarn properties are different.

In this paper, properties will be compared when they were determined on yarns spun to the twist multiplier which provides maximum static tensile strength.

The uncertainty in locating the twist multiplier for maximum strength should be kept in mind when the plots which follow are examined, since many of them depend upon the location of this unique point. Many times the strength-twist curves are flat in this region, or the twist multipliers are widely spaced, or erratic points are encountered, making the location of the twist at the reversal point partly a guess.

Although it is of no special aid in locating the point, it is believed that a semilog plot of property-twist data reveals the relations more clearly than the usual arithmetic plot. For example, the log or ratio scale as used for, say, tenacity clearly shows the up or down changes as percentages. Figure 1 shows a plot of yarn tenacity against the (all-fiber: cotton count) twist multiplier [8] for worsted wool and worsted nylon yarns, with a small inset depicting the curves as they appear on the familiar arithmetic scale. The arithmetic scale shows the curve for the low-strength wool to be flatter than the curve for the high-strength nylon, whereas the log scale shows that in percentage rates of change the curve for nylon is flatter than that for the wool.

A "shorthand" method of tabulating the more useful features of the property-twist plots has been devised, as illustrated by the two curves in Figure 1, the source for which is Townend and Marsden-Smed-

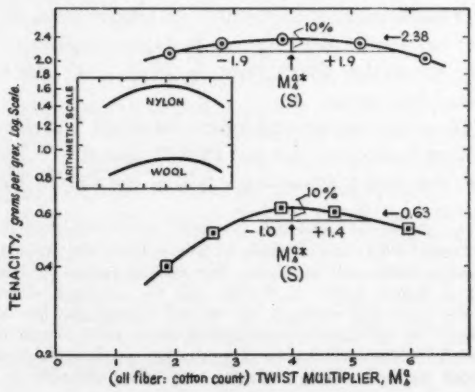

FIG. 1. *Tenacity-twist plot.*

ley [32]. The twist multiplier at maximum strength, M_{t}^{**}, is located. A horizontal line is drawn at 10% below the peak (not necessarily the best choice) to intersect the two descending branches of the curve, and the differences from the multiplier for maximum strength to the low- and high-side multipliers are read off, with that to the lower twist given a minus sign and that to the higher twist a plus sign. The data are tabulated as follows:

Kind of fiber	Cotton count	Max. tenacity (g.p.g.)	Twist multipliers (all-fiber: cotton count) Low	Max. strength	High
Nylon worsted	18s	2.38	−1.9	4.0	+1.9
Wool worsted	18s	0.63	−1.0	4.0	+1.4

Comparing with the plot, it is seen that the tabulation reproduces the features of the curves. The upper part of the curve is symmetrical for nylon, but with wool the tenacity falls off more rapidly on the low- than on the high-twist side.

In practical use, if strength falls off more rapidly on one side than on the other, then in selecting a twist multiplier we can edge away from the side on which mill variations in spinning might seriously lower the strength.

The Subdivision Ratio and the Fiber-Ends Function

Subdivision Ratio

Martindale [20] developed a formula, based on the theory of probability, for estimating variability of roving and yarns from the variability of fiber diameter and the number of fibers per cross section. Other workers in this field are referenced by Martindale. The Martindale formula, for a given kind of fiber, has been simplified by this author to read that yarn variability is proportional to the reciprocal of the square root of the number of fibers per cross section.

With this simplification as a starting point, the author has proceeded empirically. The reciprocal of the square root of the number of fibers per cross section has been named, for brevity, the "subdivision ratio," R_d. Variability of yarns at maximum strength has been plotted against the subdivision ratio and found to give straight lines. Singles yarn tenacity of maximum strength plotted against the subdivision ratio also shows a straight line. The breaking elongation of singles yarn at maximum strength likewise plots as a straight line. Further, the twist multiplier for maximum strength is also a straight-line function of the subdivision ratio.

Thus, the subdivision ratio proves to be a powerful tool in estimating yarn properties, a mathematical function combining fiber size and yarn size in one figure.

Mathematically, the subdivision ratio is defined as follows:

subdivision ratio, R_d

$$= \frac{1}{\sqrt{\text{no. fibers per cross section}}} = \frac{1}{\sqrt{n_{cs}}};$$

no. of fibers per cross section, n_{cs} = yarn denier/fiber denier = H^y/H^f;

yarn denier, $H^y = 5315/\text{cotton count} = 5315/N$;

$$n_{cs} = \frac{5315}{H^f N};$$

$$R_d = \frac{\sqrt{H^f}\,\sqrt{N}}{\sqrt{5315}} = 0.0137\,\sqrt{H^f}\,\sqrt{N}.$$

An analysis of the equation discloses that it is the ratio of the diameter of the individual fiber to the diameter of the monofil if all the individual fibers were coalesced into a monofil. The subscript d suggests both diameter and division of a monofil into fibers.

Fiber-Ends Function

Fiber length is also an element in the structure of yarns known to affect yarn properties, and the problem has been to find some simple way of handling it. If fiber length is to be taken into account in practical computations, it is desirable to include it in one mathematical function with the other structural variables, fiber linear density and yarn linear density. The latter two have already been combined in the subdivision ratio. Fiber lengths in inch units, fiber in denier, and cotton count of yarn have now been combined into one mathematical function, herein designated the "fiber-ends function," which can be shown empirically to determine yarn properties.

Development of the function was as follows: As Peirce [23] pointed out, a yarn having twisted fibers which remain parallel throughout their lengths would fall apart. Suppose that what spinning accomplishes is the snubbing down of fiber ends under other fibers by twisting. There are two fiber ends to each fiber, and

no. of fiber ends per inch of yarn

$$= 2 \times \text{fiber length} \times \text{no. of fibers per cross section} = 2 \times l \times n_{cs}.$$

Omitting the constant 2, we define a new mathematical function, having the same form as the subdivision ratio:

$$\text{fiber-ends function, } F_e = \frac{1}{\sqrt{l n_{cs}}} = \frac{R_d}{\sqrt{l}} = \frac{0.0137\sqrt{H'}\sqrt{N}}{\sqrt{l}};$$

$$(F_e)^2 = \frac{0.000188\,H'N}{l}; \quad F_e = \sqrt{(F_e)^2}.$$

If a property plots as a straight line against the fiber-ends function, then, if only one of the three variables is changed at a time, the equation affirms that the property plots as a straight line against (*1*) the square root of fiber denier, (*2*) the square root of cotton count, and (*3*) the reciprocal of the square root of fiber length.

In examining the plots which follow, it will be useful to keep in mind the meaning of zero value of the subdivision ratio and the fiber-ends function.

1. If yarn coarseness is infinite and fiber denier is finite, R_d is zero.
2. If fiber denier is infinitessimally fine and cotton count is finite, R_d is zero.
3. The fiber-ends function, F_e, is zero when cotton count is infinitely coarse (cotton count zero), as was true for the subdivision ratio.
4. The fiber-ends function, F_e, is zero when fiber fineness is infinitessimally small, as also was true of the subdivision ratio.
5. The fiber-ends function is zero when fiber length is infinite—that is, when the fibers are indefinitely long continuous filaments.

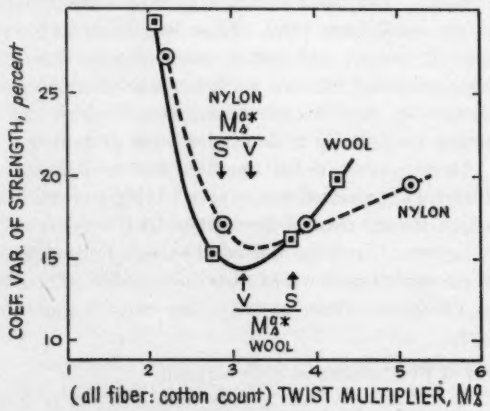

FIG. 2. *Variability-twist plot.*

PART I. SYNTHETIC STAPLE SINGLES

Since synthetics are easier to handle than cotton, and discoveries on synthetics preceded application to cotton, synthetic singles are discussed first.

For purposes of comparison of different kinds of fibers, yarn size is in cotton count and twist multipliers are in the (all-fiber: cotton count) system.

Wool is included among the synthetics because it apparently behaves substantially as synthetics do up to the point of felting, which is beyond the yarn stage.

Variability of Synthetic Staple Singles Yarns

As a preliminary, the effect of twist on the coefficient of variation of tensile strength is shown in Figure 2. The data are from Thornton and Townend [31] for wool and nylon worsted yarns of nominal 30s worsted count. On the U-shape curves the (all-fiber: cotton count) twist multipliers, M_δ^{a*}, for maximum strength, S, and minimum variability, V, are shown by arrows. The curves are typical of other such plots; from the point of minimum variability the irregularity rises steeply on the low-twist side and less steeply on the high-twist side. In contrast with the wider spacing of the twist multipliers for maximum strength, the twist multipliers for wool and nylon are approximately the same. This fact may be significant, since data on cotton and cotton system acetate also show minimum variability in the vicinity of $3M_\delta^a$. If this proves to be a general rule, it will become a simple procedure to take variability into account in the design of yarns.

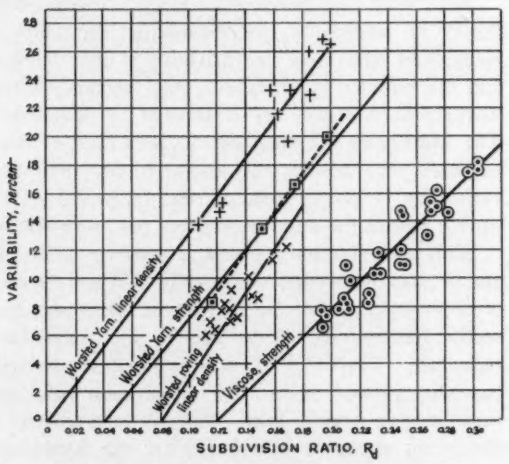

FIG. 3. *Variability of synthetics at maximum tenacity as a function of the subdivision ratio.*

In Figure 3 illustrative data are shown of the variability of singles yarns spun to maximum strength plotted against the subdivision ratio. The scale of R_d at the bottom applies only to the plot at the extreme left; the origin of the other three plots has been moved progressively to the right. Note that results with the materials yarn and roving, the properties linear density and tensile strength, and worsted and cotton systems of spinning all plot as straight lines. Table I presents relevant data on the four series shown in Figure 3 and one series not shown.

It is a great convenience to the practical use of the relation shown that the line passes through the origin —*i.e.*, the percent variability is proportional to the subdivision ratio. On the second plot from the left, the straight line has for this reason been drawn through the origin, although the dash line, not intersecting the origin, passes almost exactly through all four points.

One other feature may prove to be general for all kinds of fibers and properties. Note that the slopes of the first three curves are almost the same, especially if roving is excluded. A shortened method of computing variability, U, was employed by the German investigators and the figures of these two are also roughly the same. Since the numerical value of U is less than that of the coefficient of variation employed by the other investigators, the slope would be steeper and might be close to the others if it were possible to convert to coefficient of variation.

It may be too much to hope for, but if the slopes, all in coefficient of variation, should prove to be approximately the same, then it would become possible to estimate variability of any yarn spun to maximum strength.

Numerical example.—What is the coefficient of variation of strength of a 30s viscose yarn spun of 1.5-denier fiber, nominal 1.5-in. fiber length? Assume a slope of 120.

$$R_d = 0.0137 \sqrt{H'} \sqrt{N} = 0.0137 \sqrt{1.5} \sqrt{30} = 0.092;$$
est. coeff. of variation, $V\% = 120 \times 0.092 = 11.0$.

Experiments reported by Klompé, Wiggers, and Bakker [17] for two yarns, spun by different mills, of twists estimated to provide maximum strength showed 8.0% and 11.6%.

The reader is warned not to expect too much of this short-cut method unless and until additional data confirm that the slopes are in fact about the same, and a true "average" value can be determined; the figure 120 for the "average" slope is only for illustration. It should also be clearly kept in mind that the yarns are spun to maximum strength.

If nothing more, it should be an advantage to know that when a change is made which ups the subdivision ratio, then unevenness will increase, other things being equal; the converse is also true.

The data of Table I and Figure 3, as well as data from other sources, have been plotted against the fiber-ends function, with no apparent gain in lessened scatter or improved usefulness. On this subject Martindale [20] wrote: "equation (3) . . . shows that the irregularity of all these products arising from the random fiber arrangement depends solely upon the number of fibers per cross-section and the variability of fiber diameter; it is entirely independent of any length or other characteristics." As Martindale carefully pointed out elsewhere, however, this conclusion does not apply to the additional irregularities introduced by lack of perfection in processing. When more data are examined, it may still be found that the fiber length influences over-all variability and should be provided for mathematically.

TABLE I. SUMMARY OF RELEVANT DATA ON VARIABILITY

Source	Kind of yarn	Range	Property	Slope through origin
Martindale [20]	worsted	80's, 70's, 60's, 56's, 50's, 46's wools; 24s–62s worsted count	linear density	133
Stanbury and Byerley [29]	worsted	64's wool; 10s, 20s, 32s, 44s worsted count	strength	121
Martindale [20]	roving worsted	80's, 64's, 58's, 42's, 46's wool; 3.8–11.8 drams per 40 yds. roving	linear density	155
Johannsen and Köb [14]	viscose (cotton system)	1.5, 2.2 denier; 38, 44, 60 mm. staple; 20s, 30s, 40s, 60s, 80s cotton count	strength	98 U
Schönecker [28]	cotton	3 varieties of cotton; 20s, 30s, 42s, 60s cotton count	strength	75 U

Maximum Tenacity of Staple Synthetic Singles

Figure 4 represents a set of plots of maximum tenacity against cotton count for 1.5-, 2.0-, 2.5-, and 3.0-denier fibers. In all, there are twenty yarns and four curves. The least number of constants which would reproduce these curves is two each, or a minimum of eight constants. Each time the writer encountered these curves in Johannsen and Köb's paper [14], he despaired of finding any simple way to estimate singles yarn tenacity. It is not to be expected that anyone offered eight constants to employ for each kind of fiber is going to take the trouble to use them. And if the fiber denier or cotton count is not covered by the experimental data, can one safely extrapolate?

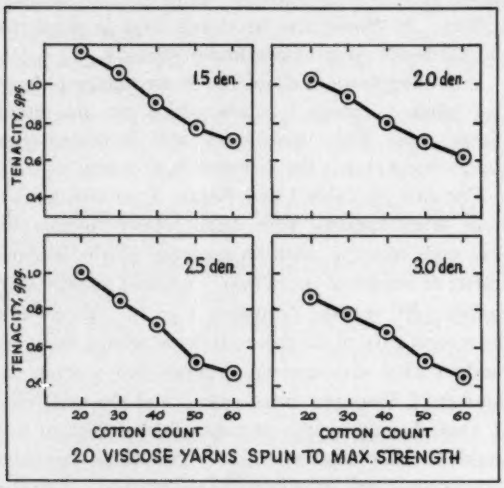

FIG. 4. *Illustration of usual tenacity plots.*

The first real thrill enjoyed by the author in his efforts to reduce textile design to engineering principles was when he plotted these twenty points against the subdivision ratio. The data thus plotted are shown on Figure 5a, line *B*. It may be seen that not only do all twenty points cluster about the same curve, but they also cluster about a straight line. It is reasonable to conclude, especially in view of the fact that data from other sources plot in the same simple way, that yarns spun of the same kind of fiber but of other fiber deniers to other cotton counts would fall on about the same straight line. The minimum of eight-plus constants has thus been reduced to two, and the ability to estimate tenacity has been extended in a fundamental way.

The other lines on Figure 5a have been selected to illustrate different sources, different kinds of fiber, and the effect of staple length, the last in lines *C1* and *C2*, where the upper line is for nominal 62-mm. length and the lower for 44-mm. length. Note that for viscose the straight lines are approximately parallel—*i.e.*, the slopes are about the same. The inset on Figure 5a shows tenacity plotted against number of fibers per cross section. The inside bottom scale is for number of fibers per cross section. Sources of the data are: line *A* [29], line *B* [14], lines *C1* and *C2* [16].

Fiber-Ends Function

We next take staple length into account by the use of the fiber-ends function. Figure 5b shows maxi-

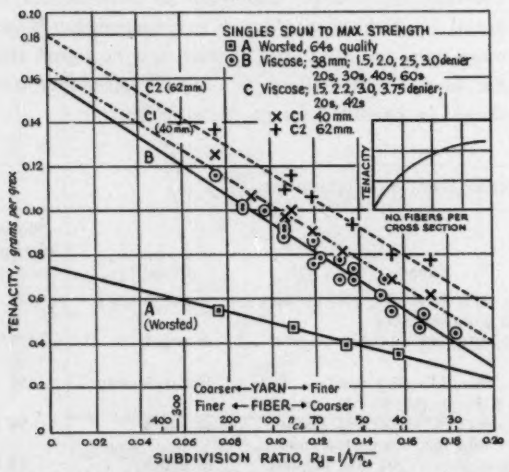

FIG. 5a. *Maximum tenacity of synthetics as a function of the subdivision ratio.*

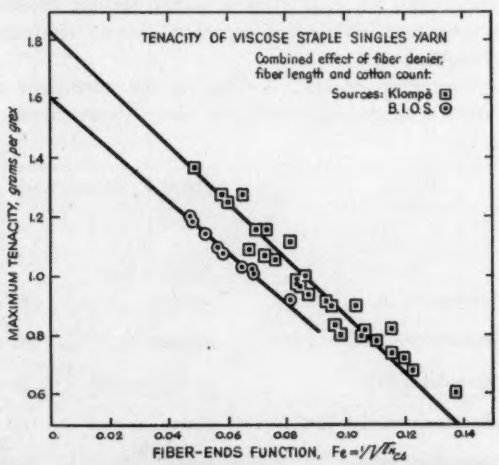
TENACITY OF VISCOSE STAPLE SINGLES YARN
Combined effect of fiber denier, fiber length and cotton count:
Sources: Klompé
B.I.O.S.
MAXIMUM TENACITY, grams per grex
FIBER-ENDS FUNCTION, $F_e = 1/\sqrt{n_{cs}}$

FIG. 5b. *Maximum tenacity of synthetics as a function of the fiber-ends function.*

mum tenacity of viscose singles plotted against the fiber-ends function. The upper line bears the same data as those for lines *C1* and *C2* in Figure 5a, with some added points, twenty-eight in all. The points now fall on one straight line. The lower line is from a different source, B.I.O.S. [2], and fiber denier ranges from 1.0 to 2.8, fiber length from 1.2 to 2.4, and cotton count is 20s. Other data, not shown, plot in the same way.

It becomes clear that the fiber-ends function is successful in handling the effect of fiber length on maximum tenacity.

For estimating tenacity, only two yarns of a given kind of fiber need to be spun and tested where the values of the fiber-ends function are reasonably far apart, a straight line is drawn through the two figures plotted, and the maximum tenacity is read off for a yarn spun of any combination of fiber denier and length to any cotton count. If the slope of the line can be estimated, only one yarn need be spun. And, finally, if fiber tenacity is known, no yarns need be spun if the intercept on zero F_e divided by fiber tenacity is approximately constant for a given family of fibers, since a starting point for the line would thus be provided (it would also be necessary to be able to estimate the slope). Published data for viscose have been examined from this viewpoint, with some indication that slopes and ratios of intercepts to fiber tenacity are roughly the same.

Break Elongation at Maximum Strength of Synthetic Singles

To my knowledge, no one has made much or any practical use of figures for the break elongation of yarns. However, this is another property which plots as a straight line against the subdivision ratio, as shown in Figure 6, the source being Johannsen and Köb [14].

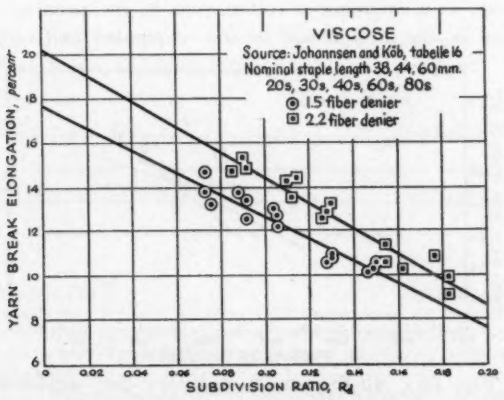

FIG. 6. *Break elongation of synthetics at maximum tenacity as a function of the subdivision ratio.*

The chief point of interest is that the intercept on zero R_d is approximately the same as that of the fiber break elongation. The figures for the two lines shown are: for 1.5 denier, intercept 18, fiber 16%; for 2.2 denier, intercept 20.4, fiber 21%.

As to possible advantages of the fiber-ends function, as compared with the subdivision ratio, Figure 6, as well as other data, have been plotted against the fiber-ends function with no apparent gain.

Twist Multiplier for Maximum Tenacity of Synthetics

Subdivision Ratio

Figure 7a exhibits the (all-fiber: cotton count) twist multiplier plotted against the subdivision ratio for various kinds of fibers for which data have been located. The unpublished data on X-51 are included through the courtesy of American Cyanamid Company. The points are well grouped about straight lines.

The twist multiplier for maximum tenacity can be estimated as shown below.

Numerical example.—What is the twist multiplier for maximum strength of a new fiber of 1.18 fiber density which is to be spun of 3-denier fiber to 22s yarn?

$$\text{subdivision ratio, } R_d = 0.0137 \sqrt{3}\sqrt{22} = 0.11.$$

Entering the plot at $R_d = 0.11$, the all-fiber twist multiplier may be taken as 2.8.

$$\text{ordinary twist multiplier, } M_s^* = \sqrt{\text{fiber density}} \times 2.8 = 1.086 \times 2.8 = 3.0.$$

Spinning experiments to define more precisely the twist for maximum strength could then be planned to cover twist multipliers on both sides of the computed figure.

Fiber-Ends Function

Löfgren [19] determined the tenacity of yarns spun of 1.02-, 1.34-, and 1.65-in. fiber and mixes of these three lengths to different twist multipliers. A lower twist multiplier was required for maximum tenacity as fiber length increased, indicating that fiber length should be taken into account. Furthermore, a plot of twist multiplier for maximum strength

against the reciprocal of the square root of the fiber length showed roughly a straight line. These facts suggest that the fiber-ends function may provide a better guide for selecting a twist multiplier for maximum strength than the subdivision ratio.

Figure 7b shows the twist multipliers plotted against the fiber-ends function, the key to the symbols being the same as on Figure 7a Fiber length ranged from 1.4 to 3.0 in. Note in comparing the Figures that the vertical scale is more expanded for F_e than for R_d.

Numerical example.—Use the same data as above and a fiber length of 1.5 in.

fiber-ends function, F_e

$$= 0.0137 \sqrt{3} \sqrt{22}/\sqrt{1.5} = 0.090.$$

Referring to the plot, an all-fiber twist multiplier of 2.8 might be selected.

est. ordinary twist multiplier, M_s

$$= 1.086 \times 2.8 = 3.0.$$

The following computations illustrate the alternative equation for fiber-ends function (which involves looking up one square root instead of three) and the use of an equation for a "representative" straight line (not shown on the plot) to replace reference to the plot.

$$(F_e)^2 = 0.000188\, H^I N/l = 0.00827;$$

$$F_e = \sqrt{(F_e)^2} = \sqrt{0.00827} = 0.091;$$

$$M_s^{**} = 1.9 + (11 \times F_e) = 2.9;$$

$$M_s^{*} = 1.086 \times 2.9 = 3.1.$$

In view of the factors discussed under tenacity, the fiber-ends plot should be more satisfactory to employ than the subdivision plot, especially for fiber lengths outside of 1.5 to 2.5 in., which is the fiber length range of most of the plotted data.

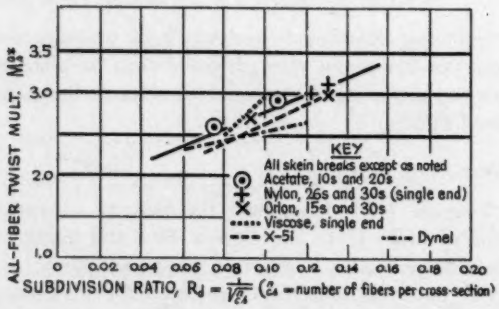

FIG. 7a. *All-fiber twist multiplier for maximum tenacity of synthetics as a function of the subdivision ratio.*

As a matter of curiosity, the twist multiplier for maximum strength of filament singles yarns is 1.7 when converted to (all-fiber: cotton count) multiplier. Since at zero F_e the fiber length may be regarded as infinite—*i.e.*, continuous filaments—then mathematically the intercept on zero F_e *ought* to be in the vicinity of 1.7; the intercept of the "representative" line, 1.9, is only slightly higher.

PART II. COTTON SINGLES

Men who work with cotton need not be told that cotton is more difficult to reduce to technical principles than are synthetics. The nature of the fiber itself is responsible. The staple is relatively short, and the fiber length varies with different varieties and also within each variety In its geometry the fiber is unique; it consists of a ribbon twisted about its axis, and it is easily bent at flat places. A bulkier yarn is produced than if the fiber were round or a flat untwisted ribbon; in fact, of the different kinds of fibers, considered with respect to yarn diameter measurements, cotton is the only fiber which definitely shows greater intrinsic bulkiness than other fibers (intrinsic bulkiness is that which is left over after fiber density is taken into account). These characteristics probably result in a special fine structure and a greater diversity of structure

Another feature of cotton which makes technical treatment more difficult is also one of cotton's commercial advantages. In the synthetic field, "Miracal" is "Miracal" (or so the fiber manufacturer would have us believe), but cotton is not cotton, but *cottons*. Thus, we must learn how to handle different varieties, and in as simple a manner as possible.

In order to be useful to the mill, the laboratory tests on a shipment of cotton must be inexpensive—that is, the tests should be few in number and each

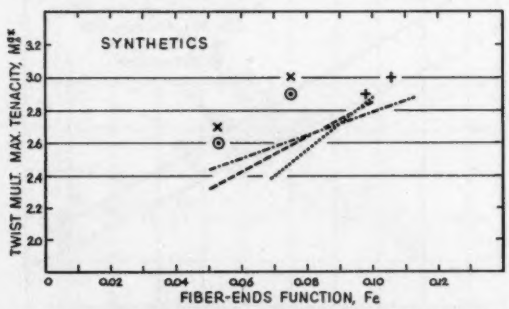

FIG. 7b. *All-fiber twist multiplier for maximum tenacity of synthetics as a function of the fiber-ends function.*

one of low cost. As a start, Fibrograph readings provide staple length, Micronaire provides fiber fineness, and modified Pressley provides fiber tenacity. With these figures we attempt to design cotton yarns and estimate properties.

Maximum Tenacity of Cotton Singles Yarn

Figure 8 presents a plot of data published by Fiori, Brown, and Sands [10, 11]. Four of the cottons were staple cut to approximately 1 in., and uncut Deltapine also had a staple length of about 1 in.

The significant feature, from the standpoint of practical usefulness, is that the slopes are approximately the same.

It is not possible with these figures to investigate the effect of fiber length; since the fiber lengths are identical, applying the fiber-ends function would produce results identical with those of the plot shown. No other data satisfactory for the purpose have been found.

It may be expected that tenacity will increase with fiber length, other parts of structure and fiber tenacity remaining unchanged, as already established for synthetics. More adequate data is required, however, for determining whether the fiber-ends function is as useful for cotton as it is for synthetics.

Twist Multiplier for Minimum Variability of Cotton Singles

Information on the twist multiplier for minimum variability can be useful. Table II lists data which were compiled by plotting coefficient of variation against twist multiplier, and attempting to read off the twist multiplier at the minimum of the U-shaped curves.

In examining the figures in the table, it should be kept in mind that coefficient of variation is a second-order effect, and that, difficult as it is to locate the reversal point for tenacity, it is still more difficult to locate it for variability. Roughly, in the table the twist multipliers for minimum variability (greatest evenness) are in the vicinity of 4. A (cotton : cotton count) twist multiplier of 4 is equivalent to an (all-fiber : cotton count) twist multiplier of 3.3, which is about that found earlier for synthetics. It will add

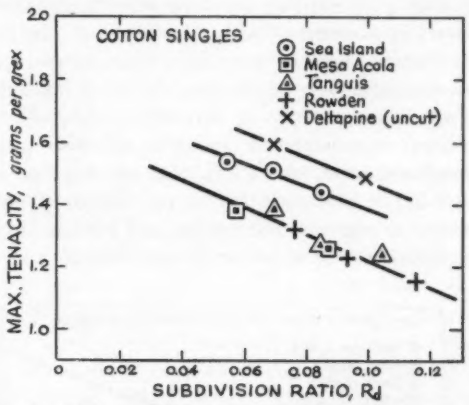

FIG. 8. *Maximum tenacity of cotton as a function of the subdivision ratio.*

TABLE II. TWIST MULTIPLIER AT MINIMUM COEFFICIENT OF VARIATION OF COTTON SINGLES YARNS

Source	Property	Cotton count	Twist multiplier at minimum variability M_e^* (V)	Remarks
Fiori, Brown, and Sands [10, 11]	strength	15.5s	3.5	Deltapine
		31s	3.9	
Schiefer and Taft [27]	strength	10s	4.2	Peeler
		80s	3.6	Upland
Schiefer and Cleveland [26]*	strength	7.4s	3.8	3, 4, 5, and 6 M_e
		15s	4.3	
		30s	4.5	
		60s	4	
Morton [22]†	strength	24s	4	3, 4, 5.5, and 7 M_e

* Coefficient of variation of break elongation of the Schiefer and Cleveland data was also plotted. Unlike strength, the curves were flat between 3 and 4 twist multipliers; otherwise, minima were at approximately the same twist multipliers as for strength.

† Fifteen cottons were investigated by Morton. Of these, ten showed minima which could not be located closer than at 4 because of the few twists. Of the others, variability was still declining at 3. The values of the coefficient of variation at the minima ranged from 11 to 15.

to the convenience of singles design if the all-fiber twist multiplier for minimum variability of yarns should prove to be in the vicinity of 3.

Cotton Singles Variability at Maximum Strength

Figure 9 shows data from Schönecker's paper [28] plotted against the subdivision ratio. As with synthetics, the points fall on a straight line. The slope is 75, which is approximately that found for viscose when the same measure of variability, U, is used. It is evident from the plot that nothing would be gained by employing the fiber-ends function, which is in agreement with the conclusion for variability of synthetics.

Similar plots utilizing data from other sources have resulted in a scatter of the plotted points. In general, tenacity-twist or variability-twist curves have been unsatisfactory for locating the twist multiplier for maximum tenacity, or for then reading off the coefficient of variation at this twist multiplier. Additional and more satisfactory data are required before it can be concluded that the plot shown is representative of a general relationship and a better "average" figure for the slope can be provided.

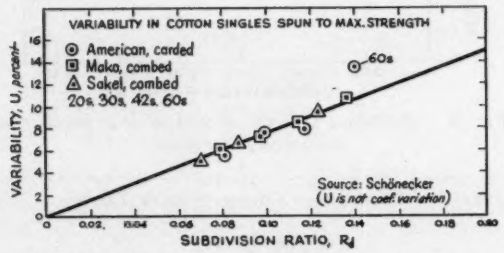

FIG. 9. *Variability at maximum tenacity of cotton as a function of the subdivision ratio.*

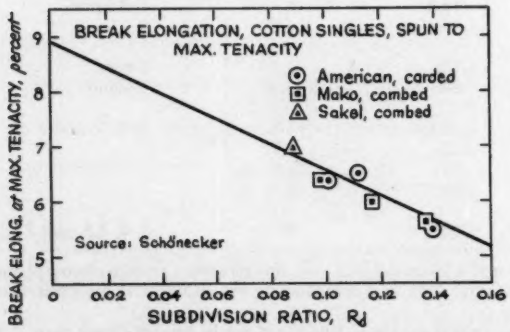

FIG. 10. *Break elongation at maximum tenacity of cotton as a function of the subdivision ratio.*

Numerical example.—Estimate the coefficient of variation of linear density of a 76s Karnak cotton yarn spun of 1.5-denier cotton fiber to maximum strength. Assume a slope of 120.

$R_d = 0.0137 \sqrt{H'} \sqrt{N} = 0.0137 \sqrt{1.5} \sqrt{76} = 0.146$; est. coeff. of variation, $V\% = 120 \times 0.146 = 17.5$.

This example was selected at random from recent literature, and it was not stated whether the yarn was spun to maximum strength; the experimental coefficient of variation was 20.5%.

Cotton Singles Break Elongation at Maximum Strength

Data for acquiring information on this factor must provide both satisfactory tenacity-twist plots and break elongation-twist plots. From the former the twist multiplier at maximum strength may be determined. The elongation-twist arithmetic plots are usually straight lines, with elongation increasing with twist. These are then entered at the twist multiplier for maximum tenacity, and the break elongation is read off. Few data on cotton which fulfill these conditions reasonably well have been encountered. Figure 10 is a plot of Schönecker's figures [28]. As with synthetics, a straight line represents the points, and the intercept at 8.8% is only a little higher than fiber break elongation of approximately 8%.

The same data have been plotted against the fiber-ends function, with, if anything, an increased scatter of the points. In this respect and in that of intercept compared with fiber break elongation, synthetics and cotton are in agreement.

Twist Multiplier for Maximum Tenacity of Cotton Singles

Subdivision Ratio

Figure 11 shows twist multipliers for maximum tenacity of cotton singles plotted against the sub-

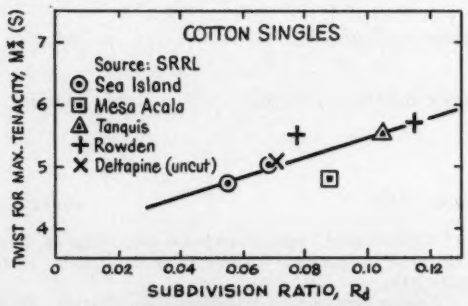

FIG. 11. *Twist multiplier for maximum tenacity of cotton as a function of the subdivision ratio.*

division ratio. Figures were read from tenacity-twist plots of data from Fiori and Brown [9] on a series of yarns spun of cotton cut to approximately 1 in. in length, and from Fiori, Brown, and Sands [10, 11] on uncut Deltapine also having a staple length of approximately 1 in. With some points omitted, for which the tenacity-twist plots left the position of the peak in doubt, the plot exhibits a straight-line relation, expressed by the equation

$$M_s^* = a + bR_d = \text{intercept on zero } R_d + (\text{slope} \times R_d).$$

In the cotton plots, both intercept and slope are higher than for synthetics.

Numerical example.—What is the estimated twist multiplier for spinning 22s to maximum strength from a cotton showing a Micronaire fineness of 4 μg./in.? Fiber denier is 0.354 × 4, or 1.42. Instead of the intercept and slope as in Figure 11, values of 3.1 and 15.5, respectively, are assumed.

$$R_d = 0.0137 \times \sqrt{1.42} \times \sqrt{22} = 0.077;$$
$$M_s^* = 3.1 + (15.5 \times 0.077) = 4.3.$$

According to Gregory [12], the twist multiplier for maximum skein strength is lower than that for single-strand strength; the data herein employed are for single-strand breaks.

Fiber denier is not the same when measured by Micronaire as by Suter-Webb. It is possible that one represents "effective denier" better than the other when applied to practical problems such as the above. It is hoped that further research will determine which should be used.

Any discussion of the twist of cotton singles which neglected reference to the fundamental investigations conducted by Gregory on yarn elements [12] would be seriously wanting. He measured twist and tenacity on the short lengths of yarn at the actual point of break. The twist multiplier for maximum strength of yarn elements was found to be: (*1*) independent of cotton count, (*2*) higher than for single-strand or skein breaks, and (*3*) widely varying from one kind of cotton to another.

The twist multipliers for maximum yarn-element strength have been plotted against the ratio of the square root of fiber denier to the square root of mean fiber length, as suggested by the fiber-ends function. The points are closely grouped about a straight line. The intercept on zero ratio converted to the all-fiber system is the same as that of the "representative" line on the plot for synthetics. Mean fiber length ranges from 0.6 for Bengals to 1.6 for Sea Island, and fiber denier from 0.9 to 2.8, respectively.

Fiber-Ends Function

Proceeding to a consideration of the effect of fiber length, it is not possible to plot the data shown in Figure 11 against the fiber-ends function, since the different cottons were cut to the same length, and Deltapine has substantially the same fiber length. Nor have satisfactory data from other sources been encountered. It is to be expected that the fiber length of cotton will affect the twist multiplier for maximum tenacity. However, unlike synthetics, which can be cut to any desired fiber length, in cotton, fiber length is not under control but must be taken as it comes. The range of mean fiber length is from about 0.6 in. for Bengals to 2 in. for Sea Island, with fiber deniers of about 3 and 0.9, respectively, fiber length increasing as fiber denier (fineness) decreases from one variety of cotton to another, with some exceptions.

In the equation for the fiber-ends function, the square root of the fiber denier appears in the numerator and that of fiber length in the denominator; hence, there is an intensification, rather than a compensation, of the two effects. The possible range of the fiber-ends function is from about 3.3 to 1, which is approximately twice that for the subdivision ratio; with adequate data it should be possible to determine readily whether or not the fiber-ends function is a better guide than the subdivision ratio for estimating twist multipliers for maximum singles tenacity.

Spinning Limits of Cotton and Synthetic Yarns

The first and most important problem is selecting the criterion to be used as a measure of the spinning limits. Various criteria have been suggested and used in the past. Of those examined by the author, the most practical would seem to be that proposed by Klompé [15], which is stated as follows: "The standards by which a given yarn count was judged still to be spinnable were the same for all the experiments, *viz.*, (*a*) a ring spinning breakage number of at most 50 breaks per thousand cops per hour at 8,000 spindle revolutions a minute and (*b*) a minimum yarn breaking length of 9 kilometers." It may be noted that this criterion takes into account both mill economics and the fact that the yarn must have some minimum degree of strength to be useful. Dis-

missing this wide subject, we turn to the problem of how spinning limits can be estimated.

At the meeting of the 1954 Cotton Research Clinic, the author suggested a method for estimating spinning limits based on a mathematical treatment originated by Wood [36] and elaborated by Klompé [15], who compared computed limits with experimental data. Subsequently, an equation has been found which is more simple to use, with little loss in constancy of the spinning-limit "constant."

The new approach is to utilize the fiber-ends function which has already been explained and applied to synthetic singles tenacity. Since the square of the fiber-ends function appears in the practical computation of cotton count spinning limit, the square has been designated the "spinning-limit constant," F_{sl}. Symbols and equations are as follows: H^f = fiber denier; H^y = yarn denier = $5315/N$; N = cotton count; N_{sl} = spinning-limit cotton count; l = fiber length (in.); n_{cs} = no. of fibers per cross section = $H^y/H^f = 5315/H^fN$; at the spinning-limit,

$$F_e = 0.0137 \sqrt{H^f} \sqrt{N_{sl}}/\sqrt{l};$$

spinning-limit constant,

$$F_{sl} = F_e^2 = 0.000188\, H^f N_{sl}/l;$$

cotton count spinning limit,

$$N_{sl} = 5315 \times F_{sl} \times l/H^f.$$

Table III gives values for the spinning-limit "constant" defined above computed with data from various published sources.

The average spinning-limit constants reported by Röder and by Cobb as the result of practical experience are in good agreement; their use leads to coarser cotton counts than the other averages. The others, aside from that reported by Millard, are also in reasonably good agreement; most of these, perhaps all, are from laboratories and not from mill practice. The figures reported by Millard for nylon as being conservative may, despite the high constant relative to the others, agree with mill experience on the cotton system, since nylon is a high-strength fiber which can be spun to finer counts on the worsted system than can low-strength wool. It is shown in the table that strong Fibro spins finer than ordinary Fibro.

There remains the problem for the mill of selecting a value for the spinning-limit constant. Processing equipment and ideas about costs lead to differences between mills. The most satisfactory procedure would probably be for each mill to determine its own spinning-limit constant. For any spinning limits already found by the mill, the spinning-limit constant can be computed and this constant used as a guide for subsequent trials; with experience, the selection of the value of the constant should increase in accuracy.

TABLE III. SUMMARY OF SPINNING-LIMIT CONSTANT FOR ESTIMATING SPINNING LIMITS

Source	Number averaged	Fiber range: Denier	Fiber range: Length (in.)	Range cotton count limit	Average F_{sl}	Range of F_{sl} multiplied by 10,000
		Viscose				
Klompé [15]	8	1.5 –3.8	1.2 –2.4	20s– 60s	0.0098	85–117
Fibro Manual [35]	7	1.5 –4.5	1.4 –2.5	16s– 72s	0.0091	68–142
Fibro Manual, strong Fibro [35]	2	1.25	1.88	80s–100s	0.011	100–125
Rayon Technology [24]	13	1.0 –5.5	1.0 –2.5	10s–100s	0.0082	58–121
Röder [25]	7	1.5 –3.75	1.6 –2.4	10s– 60s	0.0070	45– 90
		Cotton				
Turner and Venkataraman [33]	22	1.5 –3.2	0.68–1.00	7s– 42s	0.0098	61–134
Morton [22]	15	1.5 –2.4	0.75–0.91	18s– 37s	0.0127	86–166
Gulati and Turner [13]	6	0.98–2.73	0.68–0.97	8s– 40s	0.0097	60–132
		Acetate				
Cobb [5]*	3	—	1.5 –2.5	—	0.0068	59– 76
Fibro Manual [35]	1	2.5	1.42	20s	0.0086	—
		Nylon (cotton system)				
Millard [21]	1	3	1.5	30s†	0.0113	—

* Cobb gave three figures for length and number of fibers per cross section. These were stated to be based on practical experience.

† 30s is regarded as a conservative estimate; 42s spun experimentally.

In spinning cotton, it will probably be necessary to use Micronaire readings converted to fiber denier, and Fibrograph or Suter-Webb for fiber length or classer's staple length. No data have yet been encountered which provide any idea as to the results to be expected.

Numerical example.—What is the spinning limit of 3-denier, 1.5-in. Dynel? Assume a spinning-limit constant of 0.009.

$$N_{sl} = \frac{5315 \times F_{sl} \times l}{H'} = \frac{5315 \times 0.009 \times 1.5}{3} = 24\text{s}.$$

Our own mill prefers not to spin finer than 18s, although it can be done.

Computation of the spinning-limit constant based on 18s would be carried out as follows:

$$F_{sl} = \frac{0.000188\ H' N_{sl}}{l} = \frac{0.000188 \times 3 \times 18}{1.5} = 0.0068.$$

It may be observed that our figure agrees best with the figures reported by Röder for viscose and by Cobb for acetate based on practical, presumably mill, experience.

Ends-Down in Spinning

This section suffers from a lack of definite conclusions. However, the subject of ends-down is of major importance to a mill (costs, piece-rates, contentment of employees, etc.), and the section has been retained if for no other reason than to point out gaps in our knowledge which need to be filled. The variables treated are twist, yarn and roving variability, spindle speed, and fiber length, with both cotton and synthetics included.

Twist

Taking costs into consideration, in designing singles yarn it is important to know the twist multiplier for minimum ends-down. The data are meager.

Buisman's plot [3] for 42s viscose yarn shows a minimum at approximately $3M_s^{**}$ $(E\text{-}d)$; unpublished figures for acetate show the same. Steiger [30] investigated ends-down in spinning 38s cotton yarn, with results showing a flat minimum extending from about 4.4 to 5.1 (cotton: cotton count) twist multipliers; here even the beginning of the minimum is higher (converted to all-fiber) than the above figures show for viscose and acetate.

Quite obviously, generalizations on twist are not possible until further experimental data are available.

Yarn Variability

It may seem illogical to talk about the effect of yarn variability on ends-down when ends-down are, in a sense, over with before the yarn has been spun. It has been found, however, that roving variability carries over into yarn variability, and at least one investigator has shown that roving variability carries over into ends-down. More figures are available on yarn than on roving variability.

Townend and Yu [34] found that in cap spinning wool worsted yarn, ends-down increase slowly and then rapidly with yarn variability. These authors infer a break in the curve, but the data plot roughly as a straight line on semilog paper—i.e., the function is continuous.

The scanty evidence available suggests that the twist multipliers for minimum ends-down and for minimum variability are in the same neighborhood. It will be helpful if this indication proves to be even approximately the case, since ends-down experiments are more costly than variability tests.

Spindle Speed

A mill may wish to increase production or cut costs by increasing the spindle speed; or it may wish to reduce ends-down by lowering the spindle speed. In either case, a useful guide would be the ability to estimate the change in ends-down which would result from a change in spindle speed.

Buisman [3] provided two plots of ends-down in spinning 24s and 42s cotton count. The curves exhibit a sharp increase at the higher speeds. A guess was made at how the points might be plotted to produce a straight line. It was assumed that the higher breakage was caused by the centrifugal force exerted on the projecting ends of the fibers as the yarn rotated about its own axis during spinning, which may be presumed to make it more difficult for the fiber ends to be tucked down among the other fibers. Since centrifugal force is proportional to the square of the r.p.m., ends-down per 1,000 spindle hours were plotted against the square of the r.p.m., as shown in Figure 12. For 24s cotton count, the four points for r.p.m.'s between 6,000 and 9,000 lay close to a straight line through the origin. Surprisingly, data on four different makes of frame running on viscose 30s at different speeds over approximately the same range of r.p.m. as the 24s also plotted as straight lines through the origin, and these lines were only slightly lower than the line for the 24s.

The reasoning behind the use of the square of the spindle speed ties in with that which led to the fiber-ends function, and it may throw some light on differences in the fine structure of singles yarn; from our own experience we have begun to suspect, although we have not attempted to prove, that the results of twist experiments are not the same when twist is inserted on a "twist-counter" (static) as when inserted on a ring spindle (dynamic).

A compilation of published data thus far encountered (excluding wool) will give an idea of how closely the ends-down estimated from the squares of the r.p.m. may be expected to agree with experimental results. In Tables IV and V the second column shows the successive ratios for the square of the spindle speed, and the last column the successive ratios for the number of ends-down, the ratios in each case being the higher value divided by the lower value. If ends-down were proportional to the square of the speed, the ratios in the second and last columns would be the same. Ends-down are single breaks not including the result of lashes which pull down the adjacent ends.

It may be concluded from the tables that if spindle speed is changed, spinning results will be no better than the "rule of the square," and conceivably worse; in fact, this is what the data state. If the new results are very much poorer than anticipated by the rule, it may be considered worth while to improve the new spinning conditions. On the other hand, the agreement between estimated and actual results may be considered so poor that the rule is rendered useless.

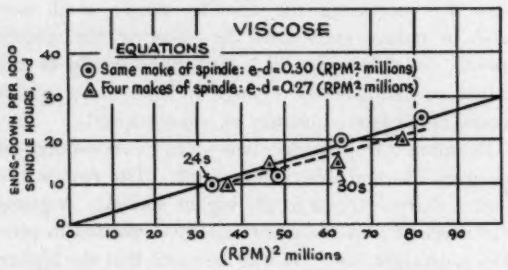

FIG. 12. *Effect of spindle speed on ends-down.*

TABLE IV. EFFECT OF SPINDLE SPEED ON ENDS-DOWN IN RING-SPINNING VISCOSE

Spindle speed (r.p.m.)	Ratio for (r.p.m.)²	Ends-down per 1,000 spindle hrs.	Ratio for ends-down
Buisman [3], 24s viscose			
5,875		10	
	1.42		1.25
7,000		12.5	
	1.31		1.60
8,000		20	
	1.27		1.30
9,000		26	
Buisman [3], 42s viscose			
8,000		20	
	1.27		1.05
9,000		21	
	1.23		1.42
10,000		30	
	1.21		1.70
11,000		51	

Staple Length

Charnley [4] reported that increasing the length of the cotton by $\frac{3}{32}$ in. halves the number of breakages. Since the longer the staple length, the fewer the number of projecting ends per unit length of yarn to be snubbed under during spinning, Charnley's re-

TABLE V. EFFECT OF SPINDLE SPEED ON ENDS-DOWN IN RING-SPINNING COTTON

Spindle speed (r.p.m.)	Ratio for (r.p.m.)²	Ends-down per 1,000 spindle hrs.	Ratio for ends-down
Steiger [30], experiment 1; 25s; twist multiplier, 4.25			
9,000		199	
	1.23		1.46
8,100		136	
	1.11		1.11
7,700		122	
Steiger, experiment 2; 38s; twist multiplier, 4.0			
9,600		281	
	1.28		1.41
8,500		199	
	1.10		1.91
8,100		104	
Steiger, experiment 3; 38s; twist multiplier, 4.0			
9,600		299	
	1.11		1.22
9,100		245	
Coulson [6]; 14s doubling weft			
5,870		29	
	1.12		1.34
6,200		39	
	1.21		2.36
6,810		92	
Coulson; 24s hosiery twist			
5,490		75	
	1.28		2.19
6,220		164	
Coulson; 14s doubling weft; 2¼-in. ring			
6,200		39	
	1.21		2.36
6,810		92	
Coulson; 14s doubling weft; 1¾-in. ring			
6,200		85	
	1.27		1.86
7,000		158	
Charnley [4]; 32s American twist cotton; lashes not stated			
7,000		16	
	1.31		1.38
8,000		22	
	1.27		3.14
9,000		69	
	1.23		1.33
10,000		92	

sult is consistent in direction with the premise underlying the effect of speed. However, fiber fineness probably changes with staple length, and a thorough analysis of the circumstances would take into account fiber weight and fiber stiffness, both of which affect the amount by which a fiber end projects under centrifugal force.

Concluding Remarks

The object of this paper was to provide some simple mathematics which would be useful in solving singles yarn problems. The solutions tentatively proposed are based on what is, without question, fundamental in the structure of singles yarn, the basis of which is the newly discovered subdivision ratio, supplemented by the fiber-ends function.

Four different yarn properties—tenacity, variability, break elongation, and twist multiplier for maximum strength—have been examined, and all plot as straight lines against the subdivision ratio, for both synthetics and cotton. Application of the fiber-ends function has permitted including the effect of fiber length on maximum tenacity and twist multiplier for maximum strength. Yarn variability and break elongation are apparently not affected by fiber length, since the fiber-ends function shows no significant gain over the simpler subdivision ratio when applied. A modified fiber-ends function provides a simple means for estimating spinning limits.

The evidence of the plots establishes that the subdivision ratio and fiber-ends function afford a remarkable simplification for the handling of the properties of all kinds of staple singles yarns.

The numerical examples of estimates of properties and spinning limits will, it is hoped, make it apparent that such computations are within the capabilities of anyone who can do arithmetic and look up square roots.

This is the bright side of the picture. There are less satisfactory features. It is emphasized that the data have at times been insufficient to justify broad generalizations. There are serious gaps in our knowledge of singles yarn. For instance, the author, being cost-conscious, especially deplores the absence of definitive data on the twist multiplier for minimum ends-down, and its relation to the twist multiplier for minimum variability.

The recasting of the equations in terms of Micronaire, Fibrograph, and modified Pressley tests is another need. The author has been forced to utilize single-fiber test results. A well-planned investigation should fill this gap.

Cotton breeders are dependent on fiber and yarn tests for guidance in the selection of new varieties for study or marketing. In the light of our new knowledge, perhaps a reappraisal of tests in current use should be undertaken.

Acknowledgments

The author extends thanks to Mr. W. E. Clark, General Manager and Vice-President, Textile Division, United States Rubber Company, for permission to publish this paper; to Miss Catherine Petrakis, who was most helpful in making computations and plots involved in working up the data; and to Mr. George Olsen, of the Advertising Department, who prepared the plots for publication.

Special appreciation is expressed to the staff of the Southern Regional Research Laboratory for making data available in advance of publication and for generous cooperation in other respects.

Literature Cited

1. Beevers, H., Thornton, P., and Wilson, D., *J. Textile Inst.* **44**, T335–46 (1953).
2. British Intelligence Objectives Sub-committee, Misc. Report No. 6.
3. Buisman, J. A. K., *Enka and Breda Rayon Revue* **6**, 74–82 (Nov. 1953).
4. Charnley, F., *J. Textile Inst.* **38**, P556–60 (1947).
5. Cobb, L. L., *Cotton* (Jan. 1946).
6. Coulson, A. F. W., *J. Textile Inst.* **38**, P535–48 (1947).
7. Dickson, J. B., *J. Textile Inst.* **44**, P514–40 (1953).
8. Dickson, J. B., *Textile World* **102**, 113–5, 243, 244, 246, 248, 250 (Oct. 1952); **103**, 128–30 (Feb. 1953).
9. Fiori, L. A., and Brown, J. J., TEXTILE RESEARCH JOURNAL **21**, 750–7 (1951).
10. Fiori, L. A., Brown, J. J., and Sands, J. E., TEXTILE RESEARCH JOURNAL **24**, 267–72 (1954).
11. Fiori, L. A., Brown, J. J., and Sands, J. E., TEXTILE RESEARCH JOURNAL **24**, 526–34 (1954).
12. Gregory, J., *J. Textile Inst.* **41**, T30–52 (1950).
13. Gulati, A. N., and Turner, A. J., *J. Textile Inst.* **21**, T561–82 (1930).
14. Johannsen, O., and Köb, H., Mitt. d. D. F-I, Reutlingen-Stuttgart, 3–12 (1939).
15. Klompé, F. H. A. M., *Enka and Breda Rayon Revue* **4**, 51–3 (1950).
16. Klompé, F. H. A. M., *Enka and Breda Rayon Revue* **4**, 46–50 (1950).
17. Klompé, F. H. A. M., Wiggers, B. G., and Bakker, A., *Enka and Breda Rayon Revue* **5**, 52–60 (1951).

18. Kochhar, P. C., *Textile Inds.* **117**, 90–3 (Jan. 1953).
19. Löfgren, S., "The Fibrogram," Gothenburg, 1950.
20. Martindale, J. G., *J. Textile Inst.* **37**, P350–70 (1946).
21. Millard, F., *J. Textile Inst.* **42**, T168–78 (1951).
22. Morton, W. E., *J. Textile Inst.* **21**, T205–24 (1930).
23. Peirce, F. T., TEXTILE RESEARCH JOURNAL **17**, 123–47 (1947).
24. "Rayon Technology," New York, McGraw-Hill Book Co., 1948, p. 4.
25. Röder, H. L., *Enka and Breda Rayon Revue* **4**, 38–45 (1950).
26. Schiefer, H. F., and Cleveland, R. S., *J. Research Natl. Bur. Standards* **27**, 325–42 (1941).
27. Schiefer, H. F., and Taft, D. H., *J. Research Natl. Bur. Standards* **15**, 237–52 (1935).
28. Schönecker, L., Mitt. d. D. F.-I. Reutlingen-Stuttgart, 1–55 (Jan. 1939).
29. Stanbury, G. R., and Byerley, W. G., *J. Textile Inst.* **25**, T295–310 (1934).
30. Steiger, J. U., *J. Textile Inst.* **38**, P561–75 (1947).
31. Thornton, P., and Townend, P. P., *J. Textile Inst.* **43**, T268–77 (1952).
32. Townend, P. P., and Marsden-Smedley, A. B., *J. Textile Inst.* **41**, T178–91 (1950).
33. Turner, A. J., and Venkataraman, V., *J. Textile Inst.* **22**, T197–223 (1931).
34. Townend, P. P., and Yu, L. T., *J. Textile Inst.* **44**, T363–79 (Aug./Sept. 1953).
35. Whittaker, C. M., "The Fibro Manual," London, Sylvan Press, 1949.
36. Wood, R., *Textile Mfr.* **74**, 134–7 (Mar. 1949).

Effect of Single and Ply Twists on the Properties of 31/2 and 15.5/2 Carded Cotton Yarns*

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Introduction

The twisting of cotton yarns into 2-ply construction is a basic operation in the manufacture of many standard fabrics. Mainly because of the complexity of the single-ply yarn twist relationship, the properties of the component yarns of these fabrics are at best a compromise of strength, elongation, diameter, and aesthetic or appearance qualities.

Some investigators have indicated that the twist in the single yarn has a decided influence on the properties of ply yarns. Since ply yarn twists are usually specified by the customer [2], mills must therefore usually resort to varying the single yarn twist in an effort to obtain maximum processing efficiency. The effect that changes in single yarn twist have on ply yarn properties is somewhat obscure. Few research studies have been reported, and the literature on the subject is rather limited in scope. Austin [3] reported that maximum ply yarn strength was obtained with a low single and a high ply yarn twist multiplier construction. In a study of "balanced" 2-ply carded cotton yarns within a narrow twist range, Zobel [6] found that "the strength ratio of balanced 2-ply yarns to the single yarns from which they were produced is constant regardless of yarn size, and increases uniformly with increases in residual single yarn twist and balancing yarn twist; but the rate of increase is greater for coarser yarns." Kershaw [5], investigating wool yarn numbers using a limited range of twists, found that changes in single yarn twist resulted in increases in strength for coarse yarns, and insignificant changes in strength for medium and fine yarns. Haven [4], in a study of multi-ply yarns ranging from 2 to 6 ply, concluded that in order to obtain maximum tensile strength, a single yarn twist multiplier between 4 and 5 should be used.

In view of the limited information available on the effect of single and ply yarn twists on ply yarn properties, and the necessity of having this type of information to pursue a study relating fiber strength to ply yarn properties, the Southern Regional Research Laboratory initiated a study of broad scope in this field. It is to include a practical range of yarn numbers and twists for single and ply yarns. This report is based on one type of cotton and two yarn numbers using a range of single and ply twists. Other work in progress has shown that the length

* This paper is based on the findings presented in two articles published in the March and May, 1954, issues of TEXTILE RESEARCH JOURNAL.

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and fineness of the cotton fibers and the yarn number influence these relationships. Therefore, these findings are only applicable for cottons which have the same general fiber properties and for the yarn numbers used in this study.

Procedures and Methods

Using the Whitin Casablanca * long-draft spinning frame ($3\frac{1}{2}$ in. gage), two yarn numbers (31/1 and 15.5/1) were spun (Z twist) from a widely grown cotton variety (Deltapine) of average fiber properties: classer's staple length, $1\frac{1}{16}$ in.; Fibrograph upper-half mean length, 1.09; mean length, 0.86; uniformity ratio, 79; Micronaire fineness, 4.3; Pressley strength index, 7.4; and maturity (NaOH), 82%. Twist multipliers (T.M.), based on the machine twist constant, for the single yarns ranged from 2.9 to 6.9 in increments of 1.0. Each single yarn twist multiplier construction was 2-ply twisted (S twist) on a Whitin twister ($4\frac{1}{2}$ in. gage), with twist multipliers ranging from 1.9 through 7.9 in increments of 2.0.

In addition, a "balancing" ply twist multiplier was combined with each single yarn twist multiplier construction in the 15.5/2 ply yarn. The "balanced" characteristic of the yarn was determined immediately after twisting by taking the yarn off the side of the bobbin and then observing whether a loop of yarn folded or twisted on itself. It is recognized that the "balanced" characteristic of a yarn is dependent somewhat on local processing conditions and the twist constructions used to produce it and that it is subject to small adjustments. Single yarn number was held constant by varying the spinning draft to compensate for the contraction due to increases in twist.

All tests and test conditions were in accordance with A.S.T.M. procedures [1]. Skein strength determinations were made on a pendulum-type tester and single strand and elongation determinations on an inclined-plane tester.

Analysis of Data

Mainly, analyses were made of ply yarn strength and elongation as functions of ply and single yarn twists for each and between the two yarn constructions—31/2 and 15.5/2. Analyses and comparisons were made from six standpoints: (*1*) varying ply yarn twist while holding single yarn twist constant; (*2*) varying single yarn twist while holding ply yarn twist constant; (*3*) equivalent single and ply yarn twist multiplier combinations; (*4*) ply-single yarn strength ratios; (*5*) equivalent yarn number comparison of a 15.5/1 yarn with a 31/2 yarn; and (*6*) variability of the ply yarns.

* Mention of trade names does not imply their endorsement by the Department of Agriculture over similar products not mentioned.

Effect of Ply Yarn Twists

Strength Data

Figures 1 and 1A show curves for the 31/2 and 15.5/2 yarns which relate ply yarn twists to skein strength when the twist in the single yarn is held constant. Generally, the trends of the ply twist-strength curves for these yarn constructions are similar. Maximum yarn strength is obtained with a low single and a high ply yarn twist multiplier combination with both constructions. However, yarn number changes cause definite differences in twist

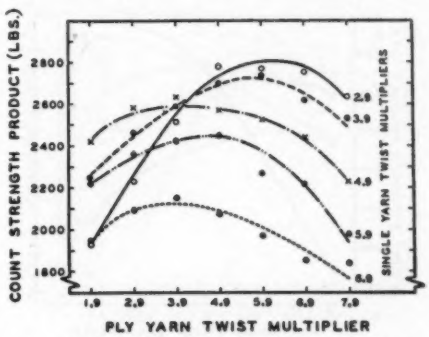

FIG. 1. *Effect of ply twist on skein strength of a 31/2 carded cotton yarn.*

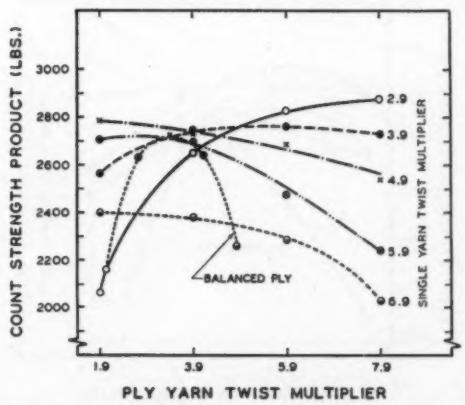

FIG. 1A. *Effect of ply twist on skein strength of a 15.5/2 carded cotton yarn.*

level required for maximum strength. Of the single yarn twist multipliers used, only yarns made with the 3.9 and 5.9 twist multipliers show distinct points of maximum strength for the 15.5/2 yarns, whereas with the 31/2 yarns all single-ply twist combinations produce points of maximum strength.

There is an area of approximately the same yarn strengths for both yarn constructions; however, this area of equal strengths is greater for the 15.5/2 than for the 31/2 yarns—that is, it encompasses a greater range of single and ply twists. This area includes a 3.9 ply yarn twist multiplier in combination with 2.9, 3.9, and 4.9 single yarn twist multipliers for the 31/2 yarns, and 3.4 and 3.9 ply yarn twist multipliers in combination with 2.9, 3.9, 4.9, and 5.9 single yarn twist multipliers for the 15.5/2 yarns.

Although each twist-strength curve has maximum strength plateaus, those of the 15.5/2 yarns are relatively broader than those of the 31/2 construction, thus permitting larger changes in ply twist without materially affecting the strength of the 15.5/2 yarns.

Figures 2 and 2A show curves which relate ply yarn twist to single strand strength when the twist in the single yarn is held constant. Generally, these twist-strength curves resemble those based on skein strength values (Figures 1 and 1A) and lead to somewhat similar conclusions. Some points of difference worthy of note are: maximum single strand strengths for low-twist single yarns are obtained at higher ply twists; the area of equal strengths is reached at higher ply twists; and certain twist constructions produce yarns having maximum strength plateaus encompassing a wider range of ply twists.

Elongation Data

Figures 3 and 3A present curves which relate ply yarn twist to elongation at break when the twist in the single yarn is held constant. Generally, ply twist

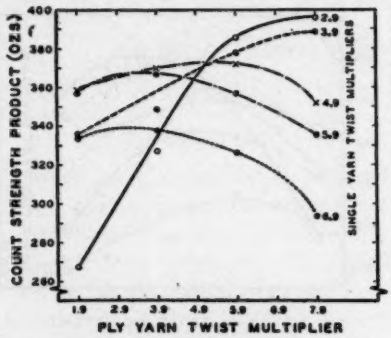

FIG. 2. *Effect of ply twist on single strand strength of a 31/2 carded cotton yarn.*

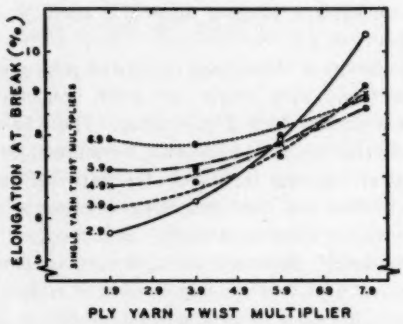

FIG. 3. *Effect of ply twist on elongation of a 31/2 carded cotton yarn.*

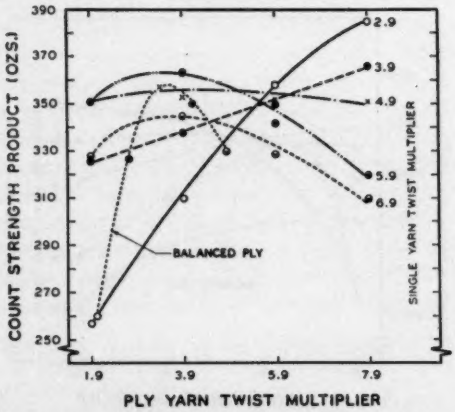

FIG. 2A. *Effect of ply twist on single strand strength of a 15.5/2 carded cotton yarn.*

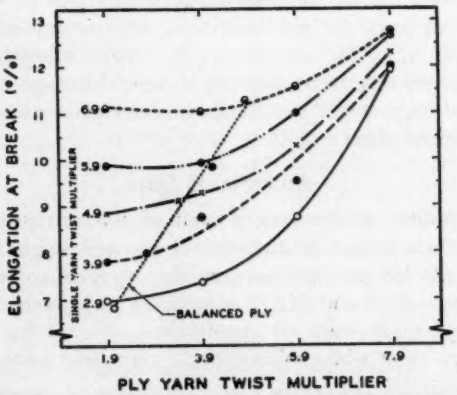

FIG. 3A. *Effect of ply twist on elongation of a 15.5/2 carded cotton yarn.*

and elongation are positively correlated—*i.e.*, increases in twist produce increases in elongation, regardless of the amount of twist used in the single yarn. Although the elongation characteristics of the 15.5/2 and 31/2 yarns are very similar, yarn number does influence these relationships. Elongation values of the coarser yarns, regardless of single-ply twist combination, are higher than those of the finer yarns. Also, maximum elongation of the 15.5/2 yarns is obtained with high single twists in combination with high ply twists, whereas for the 31/2 yarns maximum elongation is obtained with a low single twist in combination with a high ply twist.

Effect of Single Yarn Twist

Strength Data

Figures 4 and 4A show curves which relate single yarn twist to ply skein strength when ply twist is held constant. The twist-strength curves are not similar for the different single-ply twist combinations. The 1.9, 2.9, and 3.9 ply twist-strength curves are somewhat parabolic in nature, with maximum strength occurring at approximately a 4.9 single yarn twist multiplier for both yarn constructions. With the higher ply twists, the single yarn twist and ply yarn strength are linearly and inversely related. Both yarn constructions exhibit areas of approximately equal strengths between single yarn twist multipliers of 2.9–4.9 and ply twist multipliers of 3.9–5.9.

Figures 5 and 5A show curves which relate single yarn twist to ply single strand strength when ply twist is held constant. These curves are similar in character to those based on skein strengths and lead to practically the same conclusions. However, for the parabolic type twist-strength curves, higher single yarn twist multipliers are required to obtain maxi-

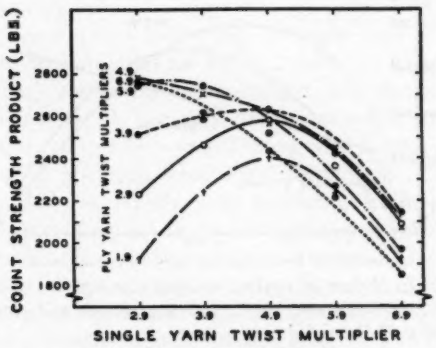

FIG. 4. *Effect of single yarn twist on skein strength of a 31/2 carded cotton yarn.*

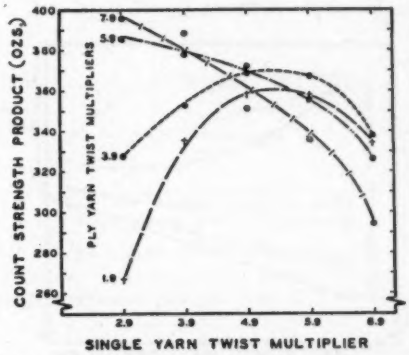

FIG. 5. *Effect of single yarn twist on single strand strength of a 31/2 carded cotton yarn.*

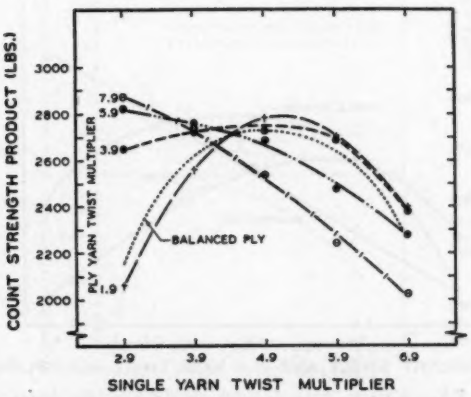

FIG. 4A. *Effect of single yarn twist on skein strength of a 15.5/2 carded cotton yarn.*

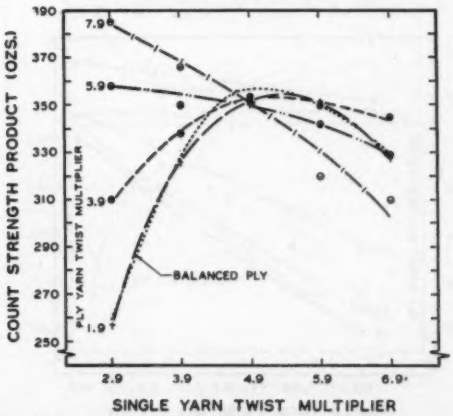

FIG. 5A. *Effect of single yarn twist on single strand strength of a 15.5/2 carded cotton yarn.*

mum single strand strengths than are required for maximum skein strengths.

Elongation Data

Figures 6 and 6A show curves which relate single yarn twist to elongation at break when ply twist is held constant. For the 31/2 yarns, elongation and single yarn twist are directly related for ply yarns twisted with 1.9 and 3.9 twist multipliers; there is no appreciable difference in elongation values over the whole range of single yarn twist multipliers when ply yarns are twisted with a 5.9 twist multiplier; and elongation and single yarn twist are inversely related up to approximately a 5.9 single yarn twist multiplier when yarn is plied with a 7.9 twist multiplier.

For the 15.5/2 yarn, elongation and single yarn twist also are linearly and directly related, regardless of the ply twist used. The rate of increase in elongation, however, is greater for ply yarns constructed with the lower ply twists.

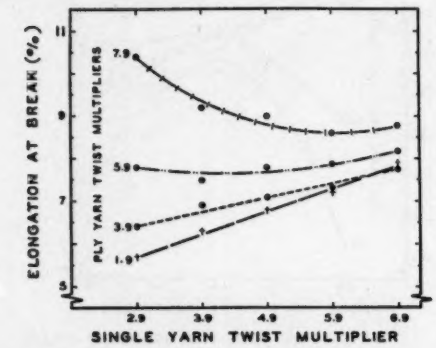

FIG. 6. *Effect of single yarn twist on elongation of a 31/2 carded cotton yarn.*

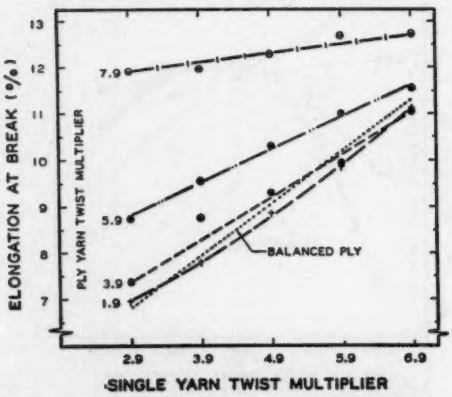

FIG. 6A. *Effect of single yarn twist on elongation of a 15.5/2 carded cotton yarn.*

Equivalent Single and Ply Yarn Twist Multipliers

Figures 7 and 7A show curves for skein and single strand strength and elongation values for 31/2 and 15.5/2 yarns spun with equivalent single and ply yarn twist multipliers. With both yarn constructions, maximum strengths are obtained with approximately a 4.4/4.4 twist multiplier combination for skein strengths and with a 5.2/5.2 combination for single strand strengths. Incidentally, the single yarn twist multipliers of these equivalent twist multiplier combinations are the ones required to obtain maximum single yarn strength. Elongation increases as twist multiplier combinations increase, with the rate of increase being greater for the coarser yarn.

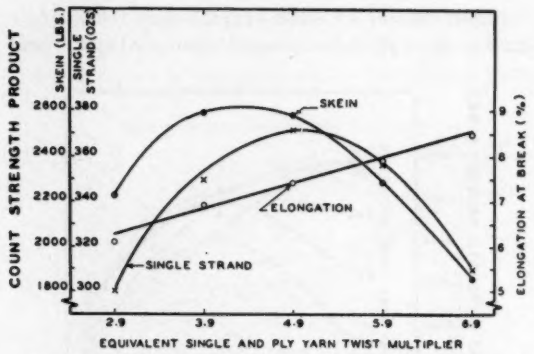

FIG. 7. *Effect of equivalent single and ply twist multipliers on skein and single strand strength and elongation of a 31/2 carded cotton yarn.*

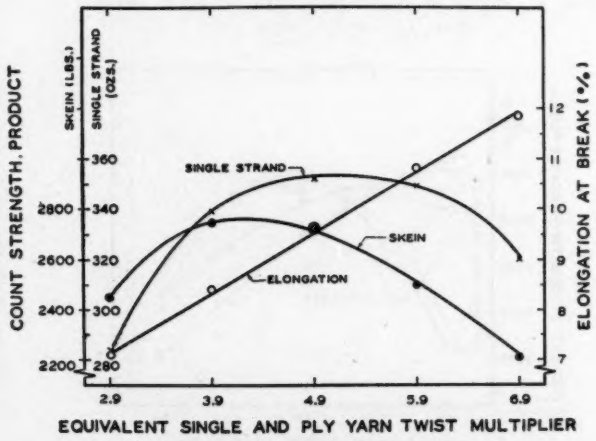

FIG. 7A. *Effect of equivalent single and ply twist multipliers on skein and single strand strength and elongation of a 15.5/2 carded cotton yarn.*

Ply-Single Yarn Strength Ratios

To determine the gains in strength (skein and single strand) of ply over single yarns, ratios of count strength products of ply to single yarns were calculated. The values plotted are based on the ply twist multiplier resulting in maximum ply yarn strength and on the equivalent twist multiplier combinations.

Figure 8 (top) shows ply to single yarn skein strength ratios for the 31/2 yarn and Figure 8 (bottom) shows the twist-strength curve for the 31/1 yarn. The largest maximum ply yarn strength ratio (1.74) was obtained with a 2.9 single and a 6.4 ply twist multiplier combination. These ratios decrease rapidly with increasing single yarn twist up to the twist multiplier (4.4 approximately) required for maximum single yarn strength. With increasing single yarn twist, the ratios increase slightly to approximately 1.20.

Figure 9 (top) shows ply to single yarn single strand strength ratios for the 31/2 yarn and Figure 9 (bottom) shows the twist-strength and elongation curves for the 31/1 yarn. The largest single strand strength ratio (1.66) was obtained with a 2.9 single and a 7.9 ply twist multiplier construction. These ratios decrease rapidly with increasing single yarn twist up to the twist multiplier (4.9 approximately) required for maximum single yarn strength. In combinations using single yarn twists higher than those resulting in maximum yarn strength, the ratios increase gradually to approximately 1.40.

The ratios of ply to single yarn skein strength based on equivalent single-ply yarn twist multiplier combinations (Figure 8 (top)) have a maximum value (1.39) with the 2.9/2.9 twist multiplier combination. Relatively speaking, these ratios are lower than those based on maximum ply yarn skein strength.

The ratios of ply to single yarn single strand strength based on equivalent single-ply twist multiplier combinations (Figure 9 (top)) have a maximum ratio (1.40) with the 6.9/6.9 twist multiplier combination. At the lower twist multiplier construction these ratios are much lower than those based on maximum ply yarn single strand strength.

Figure 10A shows ply to single yarn skein strength

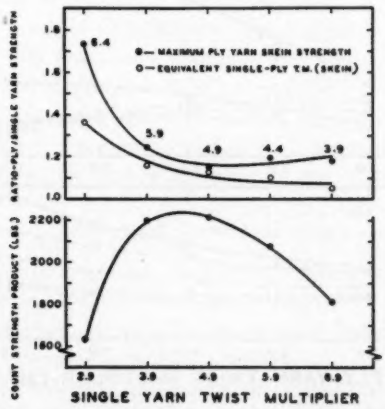

FIG. 8. Top—*Skein strength ratios of 31/2 to 31/1 yarns.* Bottom—*Skein strength count strength products of 31/1 carded cotton yarns.*

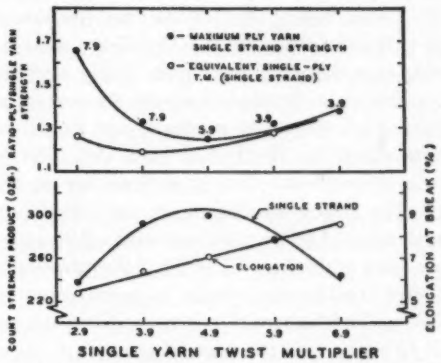

FIG. 9. Top—*Single strand strength ratios of 31/2 to 31/1 yarns.* Bottom—*Single strand strength count strength products and elongation of 31/1 carded cotton yarns.*

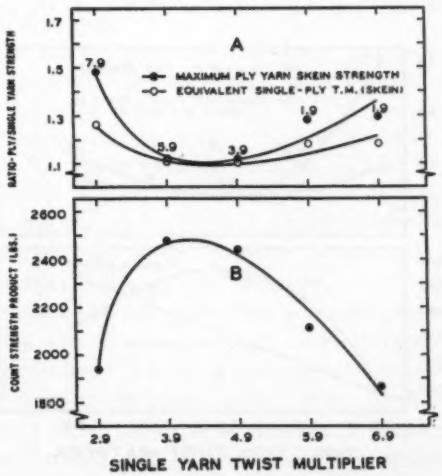

FIG. 10A. *Skein strength ratios of 15.5/2 to 15.5/1 yarns.* B. *Skein strength count strength products of 15.5/1 carded cotton yarns.*

ratios for the 15.5/2 yarn and Figure 10B shows the twist-strength curve for the 15.5/1 yarn. The largest maximum ply yarn skein strength ratio (1.48) is obtained with a 2.9 single and 7.9 ply twist multiplier construction. The ratios of ply to single yarn skein strength based on equivalent single-ply twist multiplier combinations have a maximum value (1.26) with the 2.9/2.9 twist multiplier combination. These ratios (maximum strength and equivalent twist multiplier) decrease as the single yarn twist increases up to the twist multiplier (4.4 approximately) required for maximum single yarn skein strength (Figure 10B).

Generally, these trends are comparable to those of the 31/2 yarn, except that for low- and medium-twist single yarns the ratios for the 15.5/2 are smaller, indicating that the percentage gain of ply over single yarn in this area of twist is less with the coarser yarn.

Figure 11A shows ply to single yarn single strand strength ratios for the 15.5/2 yarn and 11B shows the twist-strength and elongation curves for the 15.5/1 yarn. The largest maximum ply yarn single strand strength ratio (1.60) is obtained with a 2.9 single and 7.9 ply twist multiplier. The 2.9/2.9 equivalent twist multiplier combination results in a maximum ratio of 1.18. These curves also are similar to those for the 31/2 yarn, with the percentage gain of ply over single yarn again being less with the coarser yarn.

Comparison of 15.5/1 and 31/2 Yarns

In order to determine the relationship between a single yarn and the equivalent 2-ply yarn, the count strength product of each single yarn (15.5/1) twist multiplier construction was divided into the count strength product of each ply twist multiplier construction (31/2) whose component single yarns (31/1) were spun with the same twist multiplier as the single yarn (15.5/1).

In Figure 12, ratios *versus* ply twist multipliers for the 31/2 yarns are plotted for a range of single yarn twist multipliers used in the 15.5/1 and 31/1 yarns. Ratios for skein strength are shown in Figure 12A, for single strand strength in Figure 12B, and for elongation in Figure 12C.

Using skein and single strand values as criteria, the equivalent ply yarn is generally stronger, or equally as strong, as its single yarn counterpart for every twist construction used in this study. The skein strength of the equivalent ply yarn constructed with component single yarns spun with a 2.9 twist multiplier and then two-plied with a 2.9 twist multiplier is about 15% stronger than the 15.5/1 yarn spun with a 2.9 twist multiplier (Figure 12A).

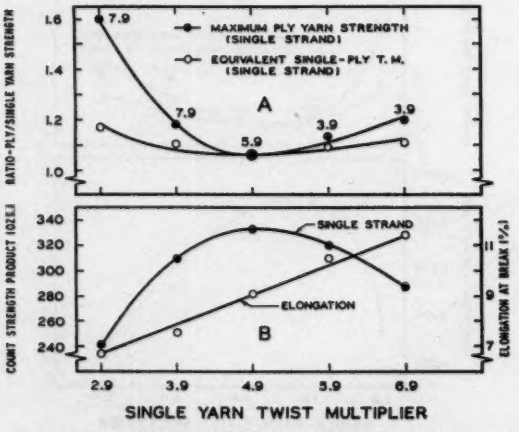

FIG. 11A. *Single strand strength ratios of 15.5/2 to 15.5/1 yarns.* B. *Single strand strength count strength products and elongation of 15.5/1 carded cotton yarns.*

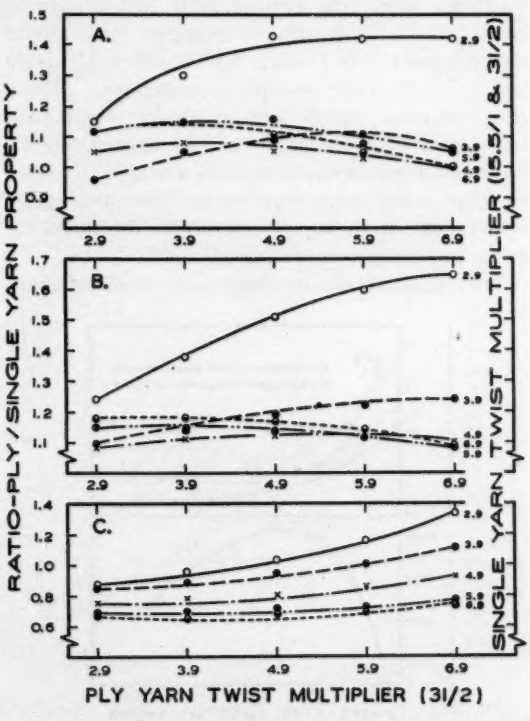

FIG. 12. *Skein* (A) *and single strand* (B) *count strength products.* C—*Elongation ratios of a single* (*15.5/1*) *yarn and equivalent ply* (*31/2*) *carded cotton yarns.*

With a 6.9 ply twist multiplier, the equivalent ply yarn is about 42% stronger than its single counterpart. The single strand strength of the equivalent ply yarn made with these same twist combinations ranges from 24% to 65% stronger than the single yarn (Figure 12B).

From these data, it is concluded that the strengths of equivalent ply and single yarns are dependent on the twist combinations used, and that within the limits of this study the equivalent ply yarn is generally stronger than its single yarn counterpart. It should be recognized, however, that this relationship is dependent on the processing organization, and particularly the spinning drafts used to spin the 15.5/1 and 31/1 yarns. Any organizational change which might cause a change in the strength of either single or ply yarns may invalidate the above relationships, and might in certain instances make the equivalent ply yarn weaker or stronger than its single yarn counterpart.

Using elongation values as a basis, the equivalent ply yarn is generally lower in elongation than its single yarn counterpart (Figure 12C). Exceptions to this are observed in the analysis of those yarns constructed with low twist in the single yarns (15.5/1 and 31/1) and high twist in the ply yarn (31/2). The elongation ratios of the ply to the single yarns decrease as single twist multipliers increase, regardless of ply twist multiplier.

Variability

Ply yarn variability was evaluated in terms of coefficients of variation of single strand and skein strength values for both yarn constructions. Analysis of the data gives some indication that ply yarn variability and single yarn twist are positively correlated, regardless of the ply twist—that is, ply yarns having component single yarns of high twist are more variable than those having component yarns of low twist.

Practical Considerations

These findings show that strength, elongation, and, indirectly, aesthetic properties of ply yarns must be compromised, since it is impossible to obtain maximum values for each simultaneously.

Since balanced, equivalent, or closely related constructions are generally required with two-ply processing, spinners probably cannot obtain maximum strength because these constructions retain Z twist in the single yarns, whereas maximum strength is obtained only after the twist in the single yarns has been reduced to zero or even reversed, being effectively S on S twist. The study shows, however, that for most constructions both single and ply twist may be varied within reasonable limits without materially decreasing strength. This information should enable cotton spinners to select those single and ply twist combinations which result in efficient production and at the same time meet use requirements adequately.

Producers of 2-ply yarns who spin their single yarns in the area of maximum strength and who use equivalent twist multiplier constructions will obtain maximum strength in their ply yarns.

Generally, comparisons of the properties of 15.5/2 and 31/2 yarns show similarity in strength and elongation trends for given combinations of single and ply twists. Changes from fine to coarse yarn numbers, however, cause changes in physical properties which are noteworthy.

A change to a coarse yarn results in definite differences in twist level required for maximum strength and in the characteristics of maximum strength plateaus. This change also causes areas of approximately equal yarn strengths to include a greater number of twist constructions.

Elongation values for the 15.5/2 yarns, regardless of twist constructions, are higher than for the 31/2 yarns. Also, as yarn number decreases, low single-twist yarns react less sensitively elongationwise to high ply twists.

For low-and medium-twist single yarns the percentage gain of ply over single yarn strength is less for the coarse yarn.

An equivalent ply yarn (31/2) is generally stronger than its single yarn counterpart (15.5/1), with strength comparisons being dependent on the twist combinations used as a basis. On the other hand, the equivalent ply yarn is lower in elongation in most cases than its single yarn counterpart.

It should be recognized that, while the evaluations of the yarns by the two test methods (skein and single strand) show the same general trends, the evaluation by the single strand method showed that slightly higher ply twists are required to obtain maximum strength. Therefore, this report presents an opportunity to spinners to make their own evaluation of results on the basis of the test method used by them.

Acknowledgment

The authors wish to express sincere thanks and gratitude to fellow staff members of the Cotton Mechanical Processing Division for processing the cotton into yarns and making the calculations and charts, and to the members of the Testing Section of the Analytical Division for making physical tests on the yarns.

Literature Cited

1. Am. Soc. Testing Materials, Committee D-13, "A.S.T.M. Standards on Textile Materials (with Related Information)," Philadelphia, 1952 (A.S.T.M. Designations: D180–52T, D414–52T, D1441–52T, and D1442–52T, and Appendix X).
2. Anon., Balanced Twist for Plied Yarns, *Cotton (Atlanta)* **103**, No. 1, 54–6 (1939).
3. Austin, D. T., Jr., The Effect of Twist on Breaking Strength in Single and Two-Ply Cotton Yarns, *Rayon and Melliand Textile Monthly* **15**, 29–30 (1934).
4. Haven, G. B., "Mechanical Fabrics," New York, John Wiley & Sons, 1932, p. 640.
5. Kershaw, S., The Effect of Single and Folded Twists on the Strength of Twofold Worsted Yarns, *J. Textile Inst.* **26**, 263–70 (1935).
6. Zobel, G., A Study of the Influence of Twist Upon the Physical Properties of Balanced Two-Ply Carded Cotton Yarns, M. S. thesis, North Carolina State College, 1951.

Nomographs for Estimating Yarn Strength

Werner Busser

Rohrschach, Switzerland

NOTE: Unfortunately, the author returned to Switzerland before the editing of this paper could be completed. Since the manuscript has been mailed to Switzerland for comment and revision, it was impossible to include the paper in this issue.

Improvements in Card Operation

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SEVERAL YEARS AGO the Clemson School of Textiles proposed to determine if the carding operation could be improved by reversing the motion of the flats. It was found that the idea had been proposed frequently throughout the history of revolving flat cards, but for some reasons the practice seems not to have had any widespread adoption. Possibly research unknown to the writer has shown that the disadvantages outweigh the advantages of the method, but, in the absence of any definite information, a study of the problem is now being undertaken at Clemson. This is a very preliminary progress report on the work begun last summer.

It seems fairly obvious that the loading of the flats while in contact with the cylinder would be quite different when run opposite to the usual direction. Also, the type of material brought out on the flats should be different for the two directions. When run to the rear, unopened tufts of cotton and pieces of trash might be brought out, which in normal operation must be cut up or pulled apart by the cylinder before they reach the front of the card. This is surely not the best use of cylinder clothing, though it is fortunate that the pieces are cut up and at least partially removed by the flats. Small areas of flat clothing, covered by such tufts, may be a cause for neps being made by the cylinder rolling cotton under them.

A study was made on the loading of card flats by cranking them off the cylinder at the rear after the card has been stopped by turning off the power with the feed in gear. This makes it possible to weigh single flat strips removed one at a time. The flats were numbered from 1 to 44 from back to front, starting with the first flat that fully contacted the cylinder at the rear of the card. This was done for both directions of running the flats, and the weights were plotted against the distance of each flat from the rear of the card. Figure 1 shows the loading of the flats for a production rate of 7.5 lbs./hr., and Figure 2 shows the loading for 13.5 lbs./hr.

It is seen that when the flats are run normally, the load from the rear to the front is almost constant, except for the two or three flats that last entered the card at the back. This shows that each flat as it enters the card is overloaded, and the cylinder soon levels it down to the constant load it will carry until it reaches the stripper at the front.

When the flats are run backward, they are clean when they enter the front of the card and slowly load as they move toward the back. They become fully loaded only as they leave the cylinder, but for the first two or three flats the load is higher than for normal running. However, part of the load carried out by each flat is picked up as it is leaving the cylinder so that many unopened tufts, seed particles, etc., are

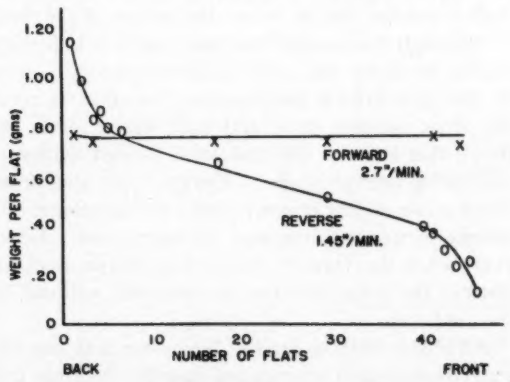

FIG. 1. *Card flat loading for 7.5 lbs./hr.*

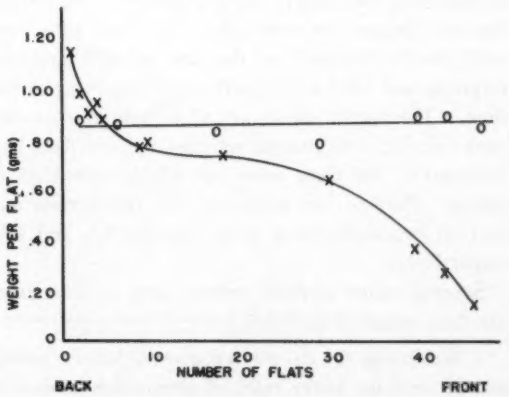

FIG. 2. *Card flat loading for 13.5 lbs./hr.*

TABLE I

APPROX. PROD. LBS/HR	FLAT SPEED IN/MIN	NEPS PER 100 SQ. IN.		TRASH IN SLIVER		% FLAT STRIP		% CYLINDER STRIP		% TOTAL WASTE		NUMBER OF RUNS	
		F	R	F	R	F	R	F	R	F	R	F	R
6	1.44	69	70	102	103	61	68	113	85	89	93	1	1
	1.90	93	78	93	103	67	81	106	90	100	94	1	
	4.00	100	84	100	97	100	115	100	75	100	110	7	4
	6.62	132	97	83	84	130	165	111	89	125	110	1	1
	24.00		117		75		480		80		248		2
8	4.00	100	88	100	96	100	130	100	75	100	104	1	1
10	4.00	100	84	100	71	100	129	100	83	100	107	1	1
14	4.00	100	103	100	97	100	120	100	84	100	102	3	3

kept from ever being worked by the cylinder. Due to this action in reverse operation, the character of the flat strip is entirely different from usual flat strips. Since properly stripping flats causes them to make less neps, it seems that the clean flats coming in from the front should catch neps off the cylinder better than when they are loaded as in normal operation.

In order to test these points, it was arranged to run the flats backward simply by uncrossing the belt that drives them, and to get several flat speeds by using different size pulleys. One-hour runs were made by manually stripping the flats at the back. The procedure is to thoroughly strip and clean the card and run it until the flats have moved more than the distance from front to back. The nep count is then carefully taken (always by the same operator), and weighings are made of the following items: (*1*) cotton fed during run, (*2*) flat strip, (*3*) cylinder strip, (*4*) fly waste, (*5*) licker-in waste, and (*6*) the sliver produced.

The sliver is then tested on the Shirley Analyser to determine the percent foreign matter. The project has only begun, but more than forty runs have been made, and it is hoped that the data are sufficiently interesting and valid to be worthwhile presenting at this time. The results shown are all for one Woonsocket card running with normal settings and speeds. Unfortunately, the data were not all on one kind of cotton. Part of the work was on rain-grown and part on irrigated cotton, staple lengths $1\frac{1}{16}$ and $1\frac{3}{32}$, respectively.

Several rather definite trends seem evident from the data compiled in Table I:

1. Reversing the flat motion gives a definite reduction in neps for lower rates of production at normal flat speeds, and there is an increased reduction in neps with decreased flat speed running them in either direction. These results are shown in Figure 3.

2. Percent foreign matter left in the web increases with lower flat speed in either direction, but is not increased appreciably above normal for speeds down to 1 to 2 in./min. (see Figure 4).

3. As would be expected, the percent flat strip rises rapidly with flat speeds in either direction, but may be less than normal even for reversed motion by reducing the speed (see Figure 5).

4. There is considerable reduction in cylinder strips for any reverse flat speed over that for forward speeds, as shown in Figure 6.

5. Total waste decreases with flat speed for either forward or reverse running, as shown in Figure 7.

6. Reversing the direction of the flats gives less reduction in neps for higher rates of production, as shown in Figure 8.

In view of the above trends, assuming they will obtain under mill conditions, it seems that in the manufacture of quality goods where the rate of carding is less than 10 to 12 lbs./hr., it would pay both to reverse and to reduce the motion of the flats.

Although there might be a small increase in foreign matter left in the web, this would be more than offset by the gain from a simultaneous reduction in neps, flat strip, cylinder strip, and total waste. It is believed that most of the additional foreign matter is lost during later processes. The gray yarn spun from sliver made in this manner shows no significant difference in strength, evenness, or appearance. However, when the yarn is dyed a deep shade, one can observe the same reduction in neps that is found in the card web.

All of the work so far has been done with one arrangement of card settings and speeds. It seems unlikely that the best arrangement would have existed

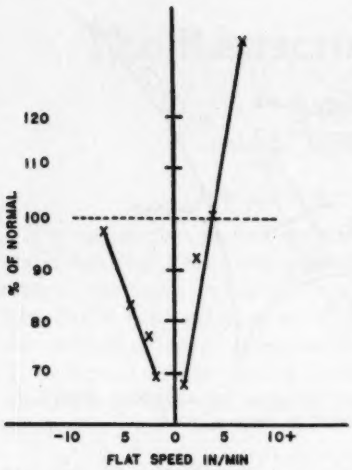

FIG. 3

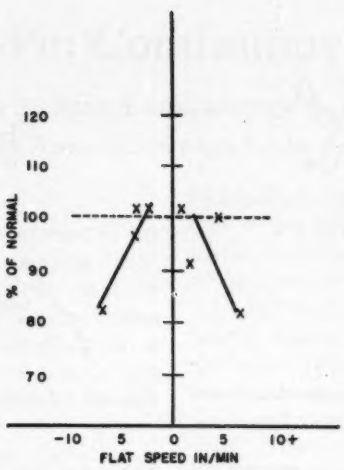

FIG. 4

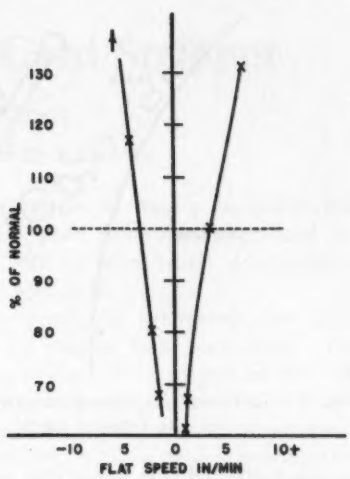

FIG. 5

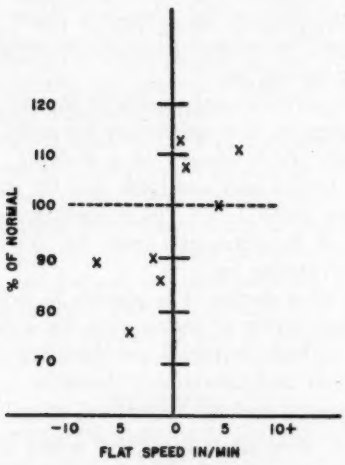

FIG. 6

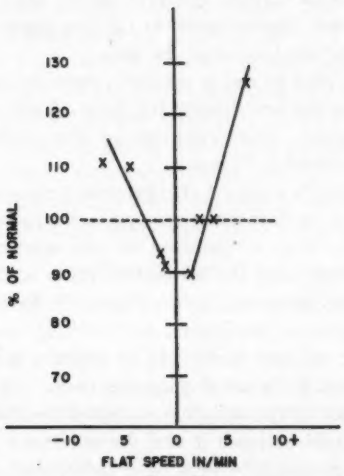

FIG. 7

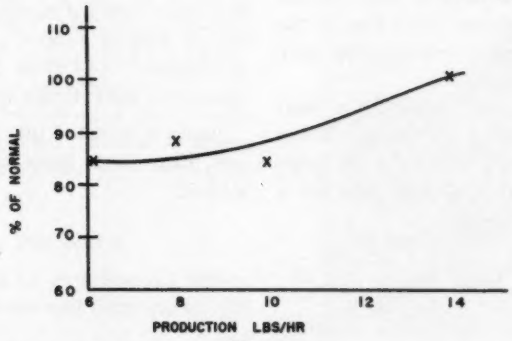

FIG. 8

FIGS. 3–8. *Graphs showing percentages of values given by normal forward speed (4 in./min.) being used as 100%.*

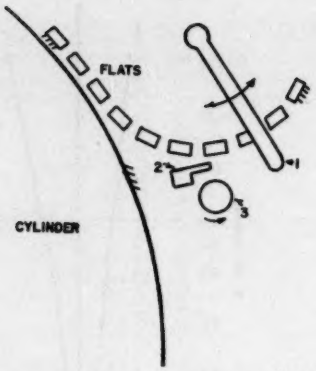

FIG. 9. *Schematic diagram of stripping device attached to front of card.*

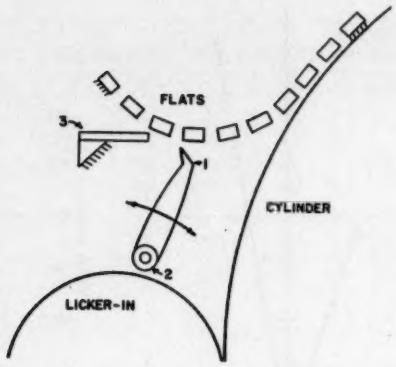

FIG. 10. *Schematic diagram of stripping device attached to back of card.*

on this card, and it is hoped that as the project advances, changes in settings, licker-in speeds, etc., will show still greater improvement in carding operation due to reversing the motion of the flats.

Putting this plan to use in the mills requires more than uncrossing the belt driving the flats. There is a stripping problem. Two solutions for this problem have been developed at Clemson.

One is a modification of the present stripper so that it will strip the flats when running in the opposite direction. The strip is gathered on the scavenger roll, as at present, and the method involves nothing different in the operator's job. Figure 9 shows a schematic diagram of the device.

The present stripper comb (*1*) is given a larger stroke by enlarging the usual operating cam. At the bottom of the stroke the stripping is carried past blade (*2*) and is caught between it and the scavenger roll (*3*), which is positively driven by a rachet and pall.

Plans are under way to develop a new type of scavenger roll which would operate at the rear of the card so that flats can be stripped before going over the top.

A second method of stripping the flats has been developed for a different kind of operation. When carding synthetic staple, there is no reason for keeping out the flat strip, and this is also the case for a number of uses for cotton when there is no objection to some additional neps.

For this purpose, the stripper is placed at the rear of the card and arranged to drop the strippings back onto the ingoing lap.

Figure 10 shows one version of this sort of stripper which seems to give satisfactory operation. A stripper comb (*1*) is pivoted on a shaft (*2*) so that it may be rocked back and forth past the flats and the scavenger comb (*3*). The strippings, as they are pushed off the scavenger comb, fall in a sheet back onto the entering lap.

With these devices it is possible to have reversed flat motion either to reduce neps for a high-quality product or to automatically put the strippings back in cases where such operation is desirable.

The present findings have raised several questions: (*1*) How does lower flat speed reduce neps? (*2*) How does reversing the motion give reduction in neps over forward running? (*3*) Why does reduction of neps by reverse motion decrease with higher production? (*4*) How does reverse running at any speed give less cylinder strip than do forward speeds?

Again it is stated that this is a preliminary report, and many more aspects of the problem are to be studied.

The Retracto-Pin Continuous Card Stripper

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Introduction

The cotton card, an indispensable machine in the textile industry, has certain inherent operating faults. One of the most serious of these is the need for periodically hand-stripping the impacted fibers from the carding cylinder. Stripping is usually done at 2- to 4-hr. intervals, thereby initiating a cycle that materially adds to mill costs and decreased product quality.

Loading of the main cylinder is the major reason for stripping; doffer cylinders remain clean for relatively long periods, and flats are stripped continuously. The idea of a continuous stripper for the carding cylinder is almost as old as the card itself, and units for this purpose have been commercially available for a number of years.

In connection with research at the Southern Regional Research Laboratory on processing chemically treated cottons, it was found that the card loaded so heavily that some out-of-the-ordinary method of stripping was required. The Retracto-Pin stripper was developed, and proved very successful for this purpose. The stripper also has promise as a practical device to aid the textile industry in processing raw cotton.

Apparatus

The Retracto-Pin stripper is a small rotor that traverses and strips the card cylinder through a slot in the back plate (Figure 1). A number of small-diameter pins or wires on the rotor remove the impacted cotton from the card clothing, and a combination of mechanical forces and self-generated air currents return these strips to the surface of the cylinder. The rotor is driven directly from the card by means of spinning frame tapes, and the slot in the back plate is sealed by a sliding metal strip.

Experimental Procedure

The new stripper is still an experimental device, and test results are preliminary and incomplete. Information on the stripper is being presented at this time to familiarize other research workers and the textile industry with possible future developments of the Southern Laboratory.

In addition to several 4-hr. test periods, two fairly lengthy tests of the stripper have been made. The first was a 30-hr. test to obtain an idea of the general mechanical performance of the stripper; card waste and sliver quality were observed but not measured. The second was a 60-hr. test to evaluate the effect of the stripper on carding performance and product quality. Unfortunately, the last test was made with an 8-in. width of the card clothing damaged by an accident to the flexible bend of the card, and time did not permit repeating this production run prior to the Cotton Research Clinic meeting.

Variety *A* cotton was a rain-grown, mechanically harvested Mississippi Delta cotton. Variety *B* was an irrigated, weather-damaged, mechanically harvested cotton with heavy grass content.

Results and Discussion

Results of the tests are presented in Figures 2 and 3 and Tables I and II.

The weight of the sliver for the 30-hr. test on variety *A* cotton ranged from 52.9 to 57.6 grains, with an average of 55.7 grains; for the 60-hr. test on

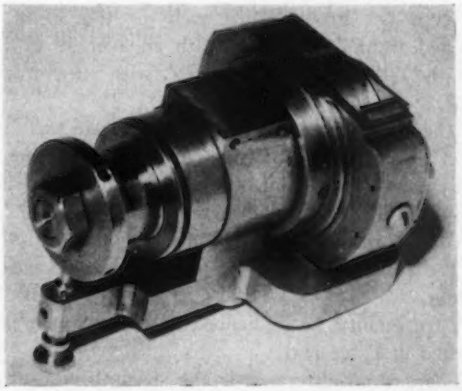


FIG. 1. *Rotor and housing of the Retracto-Pin stripper for cotton cards.*

* One of the laboratories of the Southern Utilization Research Branch, Agricultural Research Service, United States Department of Agriculture.

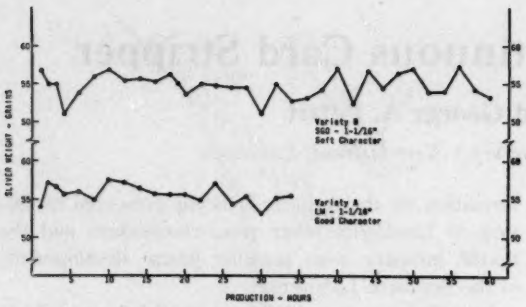


FIG. 2. *Weight of sliver produced by card with Retracto-Pin stripper attachment.*

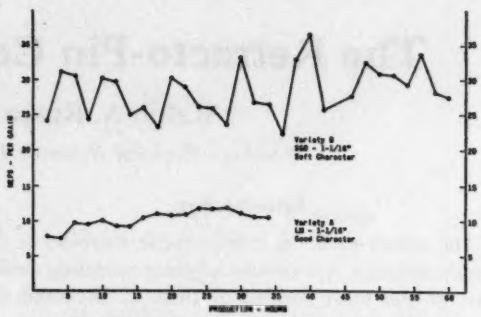


FIG. 3. *Neps in web produced by card with Retracto-Pin stripper attachment.*

TABLE I. EFFECT OF RETRACTO-PIN STRIPPER ATTACHMENT ON CARD WASTE

Waste	4-Hours production*† Without stripper (%)	4-Hours production*† With stripper (%)	60-Hours production* With stripper (%)
Flat strips	4.78	4.57	5.35
Cylinder and doffer strips	1.34	1.10	.28
Motes and fly	3.06	3.03	2.82
Sweepings	.39	.35	.36
Invisible loss	1.09	.53	.78
Total waste	10.66	9.58	9.59

* Variety *B* cotton, SGO 1 1/16 in., soft character. Carding rate, 11 lbs./hr.
† Average of three tests.

variety *B* cotton, 51.2 to 57.0 grains, with an average of 55.0 grains. These variations in weight may be compared with what the individual mill obtains over a similar period, stripping by hand at conventional 3- to 4-hr. periods.

Neps per grain in the web for the 30-hr. test ranged from 7.4 to 12.0, with an average of 10.3; for the 60-hr. test, 22.0 to 37.7, with an average of 28.7.

The effect of the stripper on card waste was favorable. Comparisons of 4-hr. card wastes without and with the stripper, and 60-hrs. with the stripper are shown in Table I. The saving of 1% of the 672 lbs. of cotton processed during 60 hrs. amounted to $1.88, on the basis of 28 cents per pound paid for variety *B* cotton.

Yarn quality, as influenced by the stripper, is indicated in Table II.

There is no difference in the strength, uniformity, and appearance of 36/1 yarns manufactured from cotton carded (4-hr. test) without and with the stripper. It is believed that the inferior yarn quality after 60-hrs. operation was the result of the damaged card clothing; the web from this part of the card was obviously nonuniform and neppy, whereas the remainder of the web was of good quality.

It is expected that improved models of the Retracto-Pin stripper will soon be placed in several mills to undergo service tests under production conditions.

TABLE II. EFFECT OF RETRACTO-PIN STRIPPER ATTACHMENT ON YARN QUALITY

Yarn 36/1	4-Hours production* Without stripper	4-Hours production* With stripper	60-Hours production*† With stripper
Strength			
Skein—corrected (lbs.)	51.4	51.5	45.5
Count strength product (lbs.)	1848	1848	1638
Single strand—corrected‡ (oz.)	7.0	7.1	6.8
Single strand—coeff. of variation (%)	13.6	13.3	16.6
Uniformity§			
Mean deviation, 4 y.p.m. (%)	18.2	18.1	21.7
Mean deviation	18.8	19.1	21.2
Grade			
A.S.T.M. appearance	C−	C	D

* Variety *B* cotton, SGO 1 1/16 in., soft character. Carding rate, 11 lbs./hr.
† Test made with damaged card clothing.
‡ Uster Automatic Single Strand Yarn Tester.
§ Uster Yarn Evenness Tester.

Cotton Carding with Metallic Card Clothing

John W. Powischill*

Proctor & Schwartz, Inc., Philadelphia, Pennsylvania

THIS PAPER reviews some of the experiences of my company with the application of metallic card clothing to cotton cards. As a builder of textile machinery, Proctor & Schwartz has been partial to metallic card clothing for many years—that is, ever since we first learned to use it and make it, over 75 years ago.

Its first use in the field of cotton was on coarse heavy machines used for the reduction of cotton threads and rags back to fiber. Very shortly after this, probably 60 years ago, the use of metallic wire had spread to carding machines for handling soft cotton stock, such as linters, and picker and fly waste. As the years passed, many new wire forms evolved and finer and finer wires were produced, until eventually we developed carding wires with as many as 86,400 points per square foot. Wires less fine than these were successfully finishing the reduction of hard twisted threads and various forms of rag and cloth waste back to fiber; and it seemed to us that if such fine wires could do this, they might also be used for carding the very finest of fibers. This led to further development work; as a result of this work, an all-metallic worsted card was introduced by Proctor & Schwartz in 1930 using metallic wire of the self-stripping type. This was quickly followed by the introduction of a card with all-metallic clothing of the same type to handle acetate and rayon, known in those days as "artificial silk." At about the same time we developed metallic clothing for asbestos cards of our own manufacture.

With this background, we began to consider applying metallic wire to cotton cards. The *American Cotton Handbook* states that metallic wire has been available in the United States since 1928. However, it appears that considerable difficulties were encountered in finding anyone interested in this matter. Again, speaking only of this company's experience, few isolated cotton cards were clothed with metallic wire during the next decade; then things remained relatively quiet during the period of World War II. However, by the end of the war we renewed our efforts in this direction, and, finally, about 5 years ago we were able to reclothe, in a single mill,† a sufficient number of cards to definitely prove that many of the things which we had found to be true in the worsted and synthetic fiber fields were also true in the field of cotton carding.

Let us now review a few of the things to be considered when metallic clothing is applied to cotton cards. The first consideration is the wire itself and the application of the wire. The wire that we are using today for the clothing of cotton cards is a tempered, fine carding wire, low in height, approximately 0.080 in. over-all tooth height. The main cylinder is wound 22 threads per linear inch of cylinder, and the doffer, 26 threads per linear inch. Main cylinder wire has 198 teeth per linear foot, giving a total of 52,270 points per square foot; and doffers have 141 points per linear foot, giving a total of 44,000 points per square foot. This, by the way, represents a step away from the older theory that wire had to be very fine and closely wound in order to card properly. Since 1940 we have run a considerable number of experiments, both in the laboratory and in the field, which have shown that under certain conditions coarser metallic wire will actually do a better carding job than finer wire.

The licker-in on the card is normally not reclothed, but continues to use the standard metallic wire used with the fillet clothed cards. The flats are not altered in any way. The regular fillet clothing used on the flats is satisfactory.

When a card is converted from fillet to metallic clothing, it is necessary to remove the fillet clothing and to apply what is known as a "base wire" in order to build up the main cylinder and doffer diameters by approximately ½ in. After accurately grinding the base wire, the metallic clothing is applied. As previously pointed out, the wire is a low-type wire with many fine sharp teeth; therefore, the manufacturing tolerances must be held very close so as to

* Chief Engineer, Textile Division.

† Gosnold Mills Corp., New Bedford, Mass. Thirty-eight cards clothed with metallic wire are now running. After this paper was read at the meeting, a colored motion picture was shown of this installation in operation.

insure a very uniform cylinder over the points of the wire. Any grinding that must be done after the cylinder is wired must be held to a bare minimum or else the points on the very fine wire will be seriously damaged. Someone may say, "Well, if this is the case, how can the card be ground subsequently?" The answer to this question is that metallic wire does not require grinding. In fact, it should not be ground, except possibly once every several years, and then only with the very lightest grind. Metallic wire has been running for over 18 to 20 years in a number of installations in the worsted field, and during this entire time the wire has never been ground, even though the production rate on a metallic clothed worsted card is often 10 times that of a cotton card.

Initial reclothing with metallic wire is a very critical operation and one which, if properly done, and barring accidents, will result in a card having a service life of probably 15 years or more. Care taken at this time will therefore pay large dividends, so the job should not be rushed and should only be done when the proper machinery and skilled help are available. In most cases this set of conditions exists only in a well-equipped reclothing plant, and it is well worth a few extra days time and a few extra dollars expense to do this work under the proper conditions.

While the cylinders are being reclothed, the card itself should be gone over and completely overhauled to put it in first-class working condition. This should include the building up of worn shafts, and the replacement or repair of worn bearings and worn or damaged mote knives, screens, and back and front plates. These steps are necessary because it has definitely been proven that metallic wire is not a cure-all. On the contrary, metallic wire operates best when the card is in tip-top shape, and probably will give a much poorer performance than fillet clothing on a card that is not properly maintained.

After the card is reassembled, it must be regaged. Gage settings normally used with metallic wire do not necessarily differ from those used with fillet clothing. However, there is a different feel when gaging metallic wire than when gaging fillet wire. This is attributed to the fact that fillet wire is flexible, whereas metallic wire is not. In the beginning it probably will require more time to gage the card, since the mechanic or overseer responsible for the gaging of the card will have to develop a new feel. However, this is not particularly difficult to do and this skill can readily be acquired by any competent worker. Recommended gagings, in inches, are as follows: (*a*) feed plate to licker-in—.007, .010; (*b*) licker-in to main cylinder—.007 Go, 0.010 NoGo; (*c*) back plate—.022, .024; (*d*) flats to main cylinder (back to front doffer)—(*1*) .012, (*2*) .010, (*3*) .009, (*4*) .009, (*5*) .007; (*e*) percentage plate— .017; (*f*) windshield—.015; (*g*) doffer to main cylinder—.005 Go, 0.007 NoGo; (*h*) comb blade to doffer—.012, .015; (*i*) main cylinder screen—front, .125; center, .034; back, .019; (*j*) licker-in screen—blank part, .028; heel, .125; (*k*) mote knives—(*1*) .010 top, (*2*) .007 bottom.

You will note that the above settings are basically tight handbook settings, except for the flats, which are even tighter at the doffer end, and the mote knives, which are set in accordance with the North Carolina State College recommendations as reported in *Textile World*, May, 1952. Our experience indicates that closer settings with metallic wire permit better carding without loss of production. Since the metallic wire is rigid, closer settings still fall in the safe range.

The speed of the main cylinder need not be changed, but it is quite likely that the doffer will have to be speeded up along with the in-feed mechanism, since the hourly production rate of a card generally increases when metallic wire is applied.

Metallic Wire *vs.* Fillet Clothing

It may be wondered why metallic wire should be considered at all. Therefore, a review of its advantages appears to be in order at this point.

Based on our experience, where metallic wire has replaced fillet clothing, hourly production rate increases can be expected. We say this with some reservation, since we have been informed that this is not necessarily true in Europe, where metallic clothing has been very widely applied to cotton cards without any increase in hourly production rates. However, there are other features in metallic wire clothing which make it worth considering even without an increase in hourly production rates. Cards clothed with metallic wire do not require stripping as we normally think of it. They do have to be cleaned every 80 to 160 hrs. to remove foreign matter that becomes imbedded in the metallic clothing, but they do not have to be stripped every several hours to remove the build-up of good usable fiber which occurs with fillet clothing. This saves time, or the cost of

automatic stripping equipment, and there is a reduction in the stripping waste. This factor alone may account for a reduction in card waste of as much as 1% or 2%. In addition, there is no gradual build-up of cotton fiber between the card cylinder wires, followed by a sudden clearing of the cylinder after stripping and then a repetition of the cycle. This means that considerably more even sliver will be delivered by the card at all times. Finally, it is not necessary to grind these cards. It has been estimated that as much as 160 hrs. a year per card are spent solely for grinding the fillet clothing. This lost time is available for production when metallic clothing is used on the card.

When the time required for grinding and for stripping is converted to useful production time, over-all production will be increased even if the hourly rate of production remains constant. Add to this over-all production increase a reduction in card waste, and the combined result is a very worthwhile saving.

Metallic clothing is said to have certain disadvantages. Let us consider these. One of its so-called drawbacks is the additional weight added by the metal necessary to build up the cylinder. This additional weight factor appears to be greatly overplayed. Approximately 500 lbs. are added to the weight of the card, and when the space around the card is considered in the floor loading, and this is a proper procedure, the card loading is distributed over approximately 100 sq. ft. Therefore, it appears that 5 lbs./sq.ft. is being added to the floor load. Further, since increased production results from the application of metallic clothing, it would appear justifiable to space the cards further apart and thereby take advantage of improved working conditions.

Another disadvantage of metallic wire, if you can call it such, is the fact that the cards must be properly maintained in order for metallic wire to operate at its maximum capacity. Instead of being considered a disadvantage, the fact that metallic wire requires good maintenance of the cards can be considered as an advantage, since good maintenance will result in the cards being kept in first-class operating condition and they will then be producing at their maximum rate.

The third stated defect of metallic wire is that when it is damaged it is harder to repair than fillet clothing. There appears to be some truth to this, but to just what degree cannot be accurately stated. Contrary to many people's belief, damaged wire can be repaired. It is not always necessary to completely reclothe the cylinders just because one spot has been damaged. Damaged wire can be removed and new wire can be applied in a great many instances. Further, minor damages can be repaired without any reclothing. With the increasing use of magnets and other devices to remove foreign materials from the cotton in the opening and picking room, all wire damage should continue to decrease. Of course, mechanics should be cautioned not to leave nuts, bolts, and wrenches around in the card room, but this should be done regardless of what type of clothing is on the cards.

Let us briefly discuss one more point—quality. In all cases, metallic clothing should produce webs of a quality comparable to those produced with fillet clothing. Nep counts should not be increased. This appears to be true whether fine or coarse cotton yarns are being made. The first major installation that we made is running in a mill making combed yarns, and these cards have produced sliver for 100's yarn and have handled up to $1\frac{9}{16}$ in. long staple Egyptian cotton. This same installation also runs $1\frac{1}{8}$ in. staple cotton for 41's yarn. At the fine installation at the Columbus Mfg. Co. in Georgia, good results were reported on a range of yarn from 15's to 43's filling yarn and 19.5's to 30's warp yarn (*Textile World*, Feb., 1953).

We have found that one or two isolated cards with metallic wire in a room full of cards with fillet clothing never produce successfully. If you are interested in metallic clothing on your cotton cards and you believe in its advantages, then you should be prepared to equip at least a portion of your card room with metallic clothed cards in order to get a fair test. One card alone is usually an orphan. As has been pointed out, it requires a different technique of gaging, it will probably run at a different rate of production, and its requirements for stripping and grinding are completely different. Very few people are going to bother with such a different object if it is the only one of its type under their care; but if a large enough number of such machines are installed to force proper care, then we are sure that the installations will be successful, both production- and quality-wise.

Does Metallic Wire Solve My Carding Problem?

Robert C. Ashworth, Jr.

Ashworth Brothers, Inc., Fall River, Massachusetts

OVER 100 years ago, Samuel Platt started the firm which later developed into Platt Freres of Roubaix, France, and J. W. & H. Platt of Harrow, England. Just about this time, in the year 1849, a Mr. F. Calvert invented saw-tooth wires.

Samuel Platt, and later his three sons, John, William, and Henry, were quick to see the possibilities of these saw-tooth wires in textile production and their application to many textile rolls, and, in fact, manufactured for M. Merelle and M. Morel the first saw-tooth wires for their experiments in covering burring rolls. These two men built equipment for removing burrs from wool, and the rolls perfected by them are used today on the modern worsted card and still bear their names. Platt also made the first serrated wires with electrically hardened points in 1895 (Patent No. 244,605) and was the first to manufacture the angle type of wire for wooden drums.

In 1924 the use of saw-tooth or serrated wires on cylinders and doffers of carding machines was started by the Platt brothers, and patents for the invention were taken out all over the world; these covered not only the clothing itself, but also the application of these wires to the cylinders, doffers, workers, and flats of all types of cards. Since that time, serrated wires, known as Platt's patent, and metallic card clothing for cylinders, doffers, workers, and flats have been used all over the world.

Approximately two years following the original development by Platt, our firm became interested in metallic wire and manufactured sufficient wire to cover several trial cards. First installations were made on all three makes of American cards in our own experimental card room, maintained at our Fall River plant, and later a few cards in local mills. No charge was made for the installation at that time due to the possibility of a patent suit. Platt had wisely patented the shape of tooth necessary to give the required number of points for suitable carding action—namely, a tooth shaped so that the height was proportionally greater than the width of the base. No American manufacturer was able to produce evidence of prior use of this shape of wire, so the patent was held valid.

During the years 1926 to 1928 Platt established a plant at Lexington, N. C., not for manufacturing, but for stocking wire and maintaining equipment and personnel to install it. The selection of installation crews was unfortunate, for not one of the group had previous card room experience. Installations made at this period of development were the mills' responsibility, as assistance in setting or running the cards was not available from the fitters.

One southern mill saw the merit in this wire at that time, and, through perseverance, experimentation, and careful training of card room help, succeeded in taking advantage of the benefit to be derived from it. This mill is completely equipped today, having clothed about 15 cards per year, until all card rooms were 100% metallic. Most of the installations made in this early period, with the exception of this one mill, were failures because of inadequate service organization.

Platt Freres closed their shop in Lexington in 1929, and contracted with Ashworth Bros., Inc., to install their patented wires in the United States and Canada. We really had a problem. Many one- and two-card installations had been made, with no guidance of how to set or care for them, resulting in very unfortunate experiences and reactions to this new development.

The period from 1929 through 1940 was spent endeavoring to win back some of the confidence required to encourage installations by mill operators. The mills who had tried one or two cards with unsatisfactory results were just not interested, and publicity about the unsuccessful ones seemed to have spread everywhere. This resulted in very few new installations during these years.

However, we were learning things about metallic wire during this period from which the mills were to benefit later on. One of the important things we found was that it is absolutely essential to sell and educate everyone in the card room (grinders, strippers, card tenders, overseers, and boss carders) on the use of metallic wire. Many of the failures during these years could be attributed to top management's directing installations of wire without consulting operating personnel. In fact, we finally came to the con-

clusion that, rather than risk failure of an installation, we would refuse the order if we were not given the opportunity to first present our case for metallic wire to those who would be responsible for its operation and maintenance.

Some of the items responsible for the failures were as follows: (*1*) installation on cards was not properly maintained (bearings badly worn, screens in need of repair, plates sprung, and many other items of poor maintenance which should have been corrected prior to application of the wire); (*2*) floors were not sufficiently rigid to allow for the close settings that are essential to successful operation of metallic wire; (*3*) reluctance of grinders and strippers to cooperate in operating cards so clothed for fear of elimination of their jobs; (*4*) fear of what would happen in case of a serious jam; also, (*5*) fear for the personal safety of operators should a strand of wire become loose.

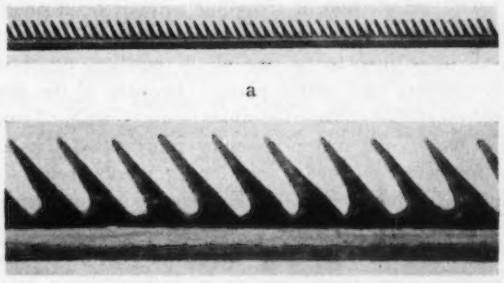
What was happening in Europe during this period? The years 1924 to 1925 were definitely the trial period. Substantial installations began between 1926 and 1927 of 1,180 cards; 1928 through 1930, 4,320 cards; the depression year, 1931, 540 cards; the eight-year period 1932 to 1939, 11,520 cards; the six years of war occupation, 1940 to 1945, 3,600 cards; the five-year period 1946 to 1950, which were years of difficulty in obtaining raw materials, 4,800 cards; the last two-year period, 1951 to 1952, of which the author has a record, 3,600 cards. This makes a grand total of 29,560 cards installed, as compared to less than 2,000 cards in operation in this country.

Why the quick response on the Continent and the slow movement here? The reasons are as follows: (*1*) There were no vacuum stripping systems, so that stripping was a real problem in continental mills. The handling of large amounts of waste was also a problem. (*2*) The saving in waste was more attractive, because all of the raw material (cotton) was imported from outside sources, and during most of these years, particularly the war years, cotton was scarce and expensive. (*3*) There was a comparatively small differential in costs between conventional flexible and metallic wire. (*4*) The journeyman's system of training personnel resulted in greater care in maintenance and operation of the cards, which is essential to the success of metallic wire.

So much for history. Now, what will metallic wire do for you? What are your basic carding problems? Quality, production, evenness of sliver, and stripping are probably the four most important considerations. With the use of metallic wire quality is improved, due to freedom from loading and the close setting permitted due to the rigidity of the wire. Since no regular grinding is required, production is increased. The wire is lightly ground when initially installed, and after that no further grinding is necessary. Normal stripping is eliminated because the wire does not fill up with fibers. All that is required is a brushing out of cylinders and doffers once every 40 to 50 hrs. to remove seed, leaf, and other impurities, according to the grade of material being carded. Due to the fact that stripping is virtually eliminated, the heavy and light variations present in the sliver before and after stripping are nonexistent. In view of the fact that no regular stripping takes place and that all the good fiber formerly taken out in the stripping operation goes into the sliver, approximately 1¼% to 1½% more good fiber is produced in the web.

When you figure that a card is out of production from 3 to 4 min. for each stripping cycle and assume three cycles per shift, the time out of production per week is from 2½ to 3 hrs. per card. Assuming a grinding schedule of once every 2 weeks and time out for grinding 7 to 8 hrs., the average card is out of production from 6 to 7 hrs. per week for these two operations.

In discussing the savings attributable to the use of metallic wire, I have purposely not indicated reduction in the number of strippers or the elimination of any grinding personnel. The grinders would have more time to do the things which they now neglect to perform in some mills, such as straightening plates, polishing screens, resetting knives, checking licker-in bearings, polishing and setting combs, adjusting flat chains, and many other jobs. This last statement is



a

b

FIG. 1. a—*Actual size of metallic wire.* b—*Same wire (magnification 30 ×) run 4 years night and day without grinding.*

wishful thinking on my part, however, because most mills with substantial installations of metallic wire eliminate about 50% of their stripping and grinding personnel.

Actual figures in saving vary greatly from mill to mill; however, we have been shown figures which vary in savings from paying for the wire in 6 months time to 2 years time—that is, a minimum of 6 months and a maximum of 2 years.

The question of durability naturally is important. Actually, no appreciable wear occurs on the points of the wire after a period of 8 to 10 years. Careful examination shows a wearing away approximately $\frac{1}{3}$ to $\frac{1}{2}$ of the way down from the point. The tips of the point become polished and are sharper. The sample of tooth shown in Figure 1b indicates the point of wear. Most of the original wire installed 18 to 20 years ago is still in operation, with no sign of wearing out. Of course, some has been replaced, due to accidents, or at least sections of it have been replaced, but the bulk of it is still producing satisfactory work.

This discussion is confined solely to the operation of metallic wire as it applies to the handling of the cotton fiber. The use of this wire on worsted and synthetic fibers is quite another story. Purposely, no exact figures have been quoted as to production, quality, evenness of card sliver, saving of waste, and labor. These figures vary greatly from mill to mill because of varying operating conditions, but I have tried to give an average over-all picture of what might be expected by the installation of metallic wire on cotton cards.

A New Development in Card Fillet

Tom Pogson

Joseph Sykes Bros., Lindley, Huddersfield, England

IN the years following World War I, due to the economic struggle and labor readjustment from the modern war industries back into commercial channels of civil needs, there were many reasons why modification in the structure of textile machines and the system of operative deployment should be made, and as the years have passed it can be said that the objective has gained in momentum. During this period much attention has been paid to the cotton cards.

The old method of stripping without hood on the hand stripper left much to be desired; also carding was considered to be one of the costliest processes on medium and coarse yarns. Because of the general condition of the card-room in many mills all over the world, the cotton industry represented the last choice when it came to jobs for the worker returning to civil industry and for the juvenile leaving school or college.

In consequence, many improvements in carding practice were attempted—from cutting down labor costs to dispensing with carding. Alternative processes of carding, under the heading of "Sliver Machines and Yarn Machines," were equally unsuccessful. The installation of vacuum strippers and vacuum pipes to the wire hand stripper was the first improvement to clean up the card-room, but at the same time large sums of money were being poured into research with the main idea of dispensing with cards altogether.

Every avenue of thought was tested; many peculiar contraptions appeared in the laboratories; some could even be said to be weird. Of course much fundamental research had to be done and all the results which were tabulated have been useful data for further development, but after 25 years, mechanical means of fiber separation had to be retained.

In the meantime, many devices and alterations were being tested on the cards, both in laboratories and in the mills, such as (*1*) metallic wire, (*2*) higher flat speeds, (*3*) combing the flat strips off the back on to the lap, (*4*) continuous strippers, (*5*) fancy rollers in every and all positions on the card cylinders, and (*6*) static plates with negative and positive potentials alleged to lift the embedded fibers to the surface of the wire.

Time and again many of the devices have been remodeled and re-presented to the spinners, all with

the object of increasing production, reducing waste, and/or obviating stripping and reducing pre- and post-stripping irregularities; however, all showed the same tendency to increase production and reduce costs, rather than to maintain or improve the quality of the sliver.

If we look back forty years, the card productions and speeds would, I think, shock most of us. I can recall that my father was very concerned in 1913 when the inside manager suggested to him that the cards should be speeded up to give 330 lbs. per week of 56 hrs., instead of the usual 280 lbs. when spinning 18's to 36's on a Georgia-Alabama-Carolina contract $1\frac{1}{32}$ in. cotton. Nevertheless there has been little change in the design of the card, and I think all will agree that mechanical cotton picking and developments in ginning practices have not made carding any easier.

The introduction of high-drafting frames and the present eagerness to dispense with as many heads of drawing as possible, as well as cutting out the finisher picker with the four lap doubling, has meant a considerable reduction in the number of doublings; in coarse counts as many as 1,200 and in the very fine counts as many as 8,000 have been cut out. Ever-increasing labor costs have also added to the urgency of this problem.

The greatest point of variation along the line of production was not hard to locate. It stood out like a sore finger. The immediate pre- and post-stripping sliver weight varied from 18% to 30%, according to the many individual mill conditions and qualities.

Obviously something must be done, and so our physicists and technicians were given the problem with the following suggestions for consideration: (*1*) eliminate stripping completely, (*2*) eliminate grinding, (*3*) increase production, and (*4*) maintain or improve quality. A considerable amount of research was done by our company in its laboratories and in the mills. It soon became apparent that not all of these conditions could be completely fulfilled, as all of the first three resulted in lowering the quality in the most important fourth condition. Also we must continue to be aware of the fact that these so-called nonstrip systems, or constant carding arrangements, always retain the stock normally stripped out as waste.

To take these conditions in order: To eliminate stripping altogether, a rigid cut tooth in a full metallic product could not be tempered as apart from the foundation in order to leave a relaxed foundation and a tempered tooth. Resilience in the tooth itself was also considered necessary, if the fibers were not to be cut or broken. The rehabilitation of the point was another essential factor, as research has shown that the most efficient carding is produced when the fiber goes in a direct line through the card, carried by the point of the tooth.

In dealing with condition (*2*), grinding, there was no doubt that no matter how perfect the cut of the tooth in manufacture, it could not be put onto the card cylinder and doffer without grinding it to a true working surface, even after surface grinding of the bare cylinder and doffer had taken place. Thus the perfect angle of the tooth is distorted even before use. Subsequent grinding decreases the efficiency of the point, and, as the angle of the point becomes more toward the right-angle, control of the fiber is lost, and side blowing in the card and cloudiness in the web becomes more apparent, due to the action of the airstream taking over control of the fiber from the points of the tooth.

The third point, to increase production, was, of course, a simple matter, as any clothing which avoids the "out of production for stripping time" and the frequent grinding periods must increase production. Without increasing speeds or grains per yard, it is, however, a very different matter, when the last condition has always to be considered, to maintain or improve quality. It became apparent that to maintain as near as possible the quality of normal card clothing, a compromise from the complete nonstripping and nongrinding card would be necessary.

By accepting the principle that a flexible wire tooth and a semiflexible foundation were the only means of a compromise with conditions (*1*), (*2*), and (*3*), while retaining the very best carding qualities, the technicians had material in their hands which could be moulded to meet all conditions.

In the tooth, the angle of work and the length of point were a matter of choice; the resilience and flexibility along with the hardness of the tooth could be controlled by the steel and tempering, and more important still, a tooth could be made that would keep its profile throughout its life, rather than decline in efficiency after a period of use. In other words, whatever happened, the point could be rehabilitated to perfection by grinding.

Accordingly, the present 8A and 9A fillets started on their way, passing through the experimental stages, with long-period tests of each prototype.

A new technique was adopted in the pattern of the clothing, knowing that 80% of the cylinder strip in normal clothing laid in the lanes between the rows of wire, and, incidentally, the long fiber in the strip was all in this position. The pattern was devoid of lanes so far as was practical, and extensive tests confirmed that not only could we avoid collection of fiber in the shallow base of the foundation, but that the generally accepted population of the teeth was now unnecessary, and the setting became more effective than the population. The optimum number of points for efficiency was very quickly found. A further point is that at present there is no lane presented to the licker-in; in other words, a tooth is presented to every point of contact with the licker-in.

The angle of the tooth controlling the absorption of the fiber and the degree of resilience of the foundation, in order to avoid the splitting up of seed and leaf or rupturing the fiber, were also factors which had to be thoroughly investigated and correlated. Extensive tests had to be made with cottons as far apart as Indian Bengals and the better grades of Egyptian cotton and on all types of man-made fibers.

In due course, we were satisfied that we had, as near as humanly possible, obtained the correct balance of the compromise.

Experience has shown us that under average conditions of carding, grinding lightly for about 1 hr. with a good abrasive once every 1,000 hrs., is sufficient to maintain maximum carding efficiency. The abrasive for this toughened wire is very important and we recommend Behr-Manning's aluminum oxide 30's grit, or Dronsfield's Aitox, a special manufactured abrasive for this clothing. Also I must emphasize that this type of clothing is a precision job and should be treated as such. Indiscriminate grinding and setting will devoid it of all the advantages it offers.

Stripping under average conditions will be in the neighborhood of once per 40 hrs. on cotton, while for synthetic fibers, once per 120 or up to 500 hrs. has been practiced.

On the general performance of this clothing, I could quote masses of figures which, although not contradictory, vary widely under different conditions. I can, however, lay down certain standards: (*1*) that the actual carding and efficiency of this clothing throughout its long life is equal to the quality of normal card clothing, although we must be mindful of the normal strip lint being included in the web; (*2*) the pre- and post-stripping variation, while not totally excluded, is well within the normal variation of the lap.

The production is increased in proportion to the saving in stripping and grinding time. The flexibility of the wire and foundation reduces fiber breakage and the cards are clean in contrast to their dirty condition when cut-tooth clothings are used.

Clemson Pretwister for Roving Frames

Hugh M. Brown

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IT IS NOT USUAL that improvements in processing (or in anything else, for that matter) can be had at no extra cost, but such seems to be true with a new development at Clemson.

When making roving normally, the strand between the top of the flyer and the front drafting rolls has very low twist. This is due not only to the fact that the final twist in roving is low, but also to the fact that the full twist does not get out of the top of the flyer and travel up the strand to the front rolls. Usually, for some distance from the front roll there is practically no twist. Because the strand passes out through the hole in one side of the top of the flyer, it is vibrated back and forth, which keeps it whipped slack by stretching it at its weakest places. This effect is especially bad for heavier roving, for which the twist is lower and the mass being whipped is higher.

If there were some way of increasing the twist between the top of the flyer and the rolls, this would

prevent such stretching of the weak places and make better roving. Extra twist in this region would have to be "false twist" and not add any to the final desired twist in the roving.

It so happens that the Clemson School of Textiles has developed a method of adding false twist to yarns to reduce ends down in spinning. The same principle—twisting by rolling the strands—can be used on roving frames. For spinning frames, the yarns pass over the edge of rubber rollers mounted in the thread guides and driven by a belt along the side of the frame. (An article on the method is being published in *Textile Industries.*) Instead of rollers, the patents also covered the use of rotating rubber eyes to be built in each thread guide. For the roving frame, the method is simplicity itself, because each flyer top is already a rotating eye. Instead of keeping these eyes nicely polished, they need only be covered with rubber, which, by rolling the roving, can add as much as 200% extra twist between the flyer and the front rolls. This extra twist is all false and does not follow the strand beyond the top of the flyer. The rubber may be applied in any of the following ways:

1. A rubber sleeve may be placed around the flyer top, with the edge of the sleeve slightly above the metal. This can be done nicely by cementing ½-in. pieces of gum-rubber tubing around the tops of the flyers.

2. The hole in the flyer top may be reamed out, and a rubber sleeve placed inside projecting slightly above the metal.

3. The top of the flyer may be coated by painting, spraying, or dipping with rubber paint. The action is better if the hole is first reamed out to approximately 1 in. diameter.

4. Rubber-coated metal sleeves may be placed over or inserted in the flyer top.

Plans are under way to have special sleeves made by one of the rubber manufacturers.

The operation of the frame is not changed in any particular way. Only the results are different. They may be summed up as follows: (*1*) many fewer ends down; fewer splices to affect the yarn; (*2*) more compact roving and harder bobbins, so that more can be carried by each bobbin; (*3*) possibility of running with less twist; hence, more production and better spinning; (*4*) more even roving; unevenness reduced 20% to 25% for heavy roving; (*5*) possibility of a practical stop motion, due to having firm strands between flyer and rolls; (*6*) roving unwinds better at spinning frame and gives more even yarn.

All of the above advantages can be had for nothing more than the cost of a rubber band or a dab of paint for each spindle.

The method is not as effective on fine roving from high-draft frames, because it is already given higher twists and, being so light, the weak places are not stretched by whipping so badly as in heavier roving. It is believed that there would be some gain, however, and that this should make stop motions more practical.

A nice way to demonstrate the twist is to run colored roving along with the sliver in a normal end and one with the rubber band. The one with the rubber top will often show more than three times the twist. It was found both at Clemson and in a textile mill that the higher the false twist, the greater the improvement in evenness.

Clemson School of Textiles welcomes anyone interested in seeing this simple improvement in operation.

Developments in Cotton Blending and Feeding

Howard H. Langdon

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THE development work reported herein was first undertaken by the Consolidated Machine Tool Corporation of Rochester, New York, as a program for diversification of product. Later on the Curlator Corporation was set up, which is now an independent organization developing and selling new and unique machinery in both the textile and wood pulp processing industries.

Certain patent rights were acquired from F. M. Buresh of Blandford, Massachusetts, who had developed an experimental model of a machine for the formation of random oriented webs from various textile fibers, principally cotton, wool, and certain synthetics—both staple and waste, but primarily waste fibers. Based on the experience gained with the experimental machine, a full scale Rando-Webber was designed. This model was 40 in. in width and the first runs of fiber were made in the Fall of 1947. A second machine was built in 1948 and several in 1949.

The Rando-Webber was fed from mill run picker laps. The widthwise air-flow pattern in the air and fiber conveying ducts of the machine and static electricity were, and have been, continuing problems, but both were of minor consequence compared to the problem of nonuniformity of picker laps used for feeding the machine. Although the Rando-Webber actually improved the uniformity pattern of the picker lap, the resulting product web was unsatisfactory.

The next step was to design and build a feeder that would meet more precise requirements. It was soon discovered that those items of design and manufacture, lifted from conventional textile practice, were to be the source of our most exasperating problems. This is probably so because we expected the particular parts to function properly due to their long use in the industry.

First, there will be a brief discussion of the operation of the Rando-Webber and Rando-Feeder (see Figure 1) and some of the innovations which were incorporated in the machines. This will be followed by a detailed description of the essential features of the feeder.

The hopper, elevating apron, and stripper adjacent to it are more or less conventional. The stripper rotor turns 600 r.p.m. and reduces the overfeed to small tufts of fibers caught on the individual pins. The smaller the tufts remaining on the pins after the stripping action, the better the subsequent action and product. In normal operation these small tufts travel down the back side of the elevating apron and come under the influence of a stream of air entering the air bridge.* The tufts pack into the air bridge under suction pressure and are carried forward between a screen belt and conveyor rolls. The feeder mat so formed is fed to the feed roll of the Rando-Webber much the same as picker lap would be fed. Width-

* The action at this point is shown to better advantage in Figure 2, and will be explained in detail later on.

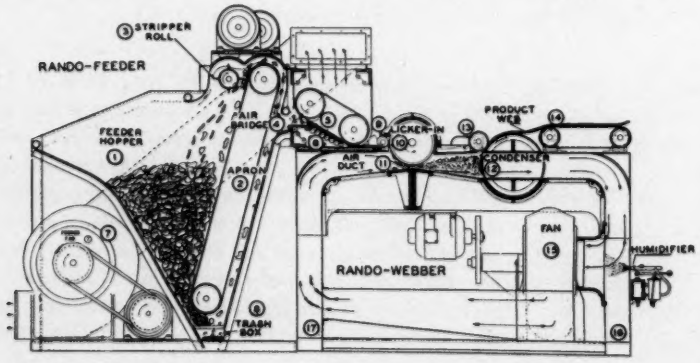

FIG. 1. *Flow diagram, combined Rando-Feeder and Rando-Webber.*

wise and longitudinal uniformity are established in the air bridge.

The feed plate, nose bar, and feed roll are more or less conventional with the exception that the nose bar may have teeth at the working point adjacent to the licker-in. We have laboratory evidence that the teeth improve the opening of fiber; in any event, plucking is materially reduced.

The licker-in turns 2200 r.p.m. A high-speed unit, 9 in. in diameter, it is carefully designed, manufactured, and balanced. It is wired in the conventional manner and the wire is swedged in the grooves.

The condenser is 12 in. in diameter in the 40-inch Webber with the air flow straight through so as not to set up unwanted air currents or turbulence pockets that might upset the lay of the fiber when forming the web. This is in contrast to end removal of the air found in conventional condensers.

Another important innovation is the recirculating air system and the humidifying system incorporated within the Rando-Webber. In this respect there is effected a reduction of static electricity when the internal circulating air is warm and relatively humid. There is a noticeable difference in static electricity generation and its effect on web uniformity when operating on the various kinds of fibers. Our work with respect to static electricity and its control is an interesting story; however, it will be omitted at this time.

Several years of work have also been done to assure a uniform product web from the standpoint of air flow in the circulating system. Again a recirculating system of air flow affords the best opportunity to control the widthwise uniformity of the airstream and the avoidance of turbulence pockets. We are now in possession of fundamental knowledge and data that permit correction of nonuniformity in this respect and the designing of machines 60 in., 84 in., or even wider.

We wish to discuss the Rando-Feeder particularly and to suggest that it may have a broad field of use in the cotton industry.

In order to show why this may be true requires a closer look at its unique features (see Figure 2). This figure shows a cross section of the screen box and air bridge and the down travel of the elevating apron. A suction pressure exists in this screen box, provided by the fan (*7*) shown in Figure 1.

A screen belt running over 6-inch rolls is made from wire mesh of the type ordinarily available from people furnishing Fourdrinier wire for paper machines. The techniques of forming and seaming available to the paper people are at our disposal. On the paper machine the belt may be 120 in. wide and travel 1800 ft. a minute, while in our case it is 42 in. wide and may travel 10 ft. a minute.

The normal air-flow pattern is shown by lines and arrow points. The air bridge (*4*) is trumpet-like in cross section and 40 in. wide. Small tufts of fiber are present on the elevating apron pins which will travel with the elevating apron in a complete cycle unless removed by action of the air bridge. Metal, along with trash, is largely freed by the opening action of the stripper. All metal and considerable trash that is heavy or dense will not be carried into the air bridge by the airstream. The metal and trash collect in the trash box at the bottom of the elevating apron. We have seen fine tag tie wires carried across the air bridge but we know of no case where heavier pieces such as pins, rings, nuts, screws, etc., have been carried across to cause injury to operating parts.

The feeder fan, elevating apron, and adjacent stripper can be started and may continue to run indefinitely without the removal of fiber by the screen box. The screen belt is operated and controlled from the subsequent processing machine or the Rando-Webber. With the feeder turned on, the air bridge fills with tufts of fiber which are compacted with the suction pressure of the fan, and this compacting of fiber in the trumpet-like opening closes off the flow of air more or less completely. There is, under this condi-

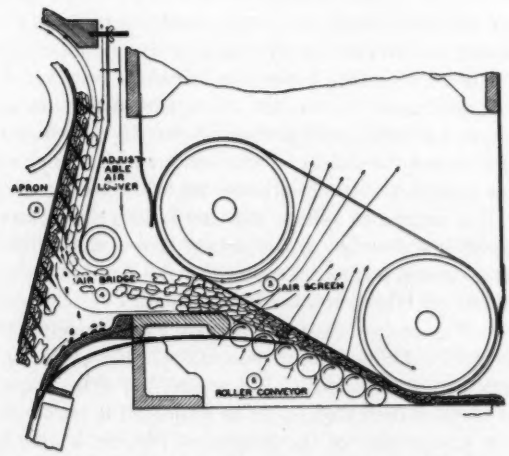

FIG. 2. *Air-bridge and screen-box details.*

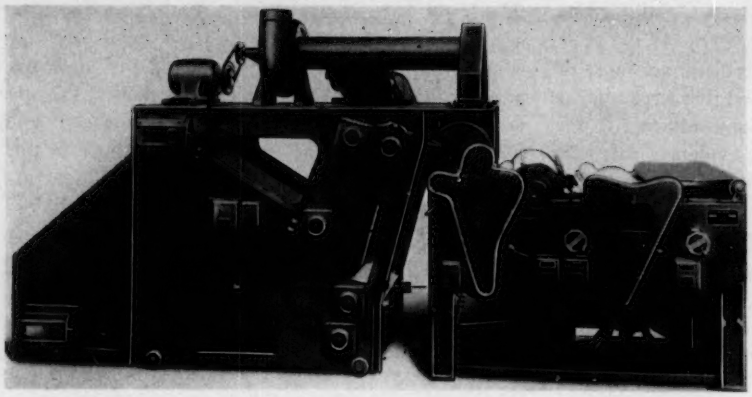

FIG. 3. *Model 40-B Rando-Feeder joined to Model 40 Rando-Webber.*

tion, no flow of fiber tufts from the elevating apron to the air bridge simply because there is no air flow to cause stripping from the apron pins travelling by.

When the screen belt is started, the belt, combined with the suction pressure, causes fiber to flow forward in the air bridge. Immediately, a feeble air flow is established which strengthens as the fiber in the air bridge moves forward. A tuft of cotton requires only a gentle movement of air to carry it from the pins to the throat of the air bridge. With the forward movement of fiber more or less velocity of air flow is established and the tufts are stripped and packed into the air bridge as needed to make up the feed mat that is being delivered.

Further, and most important, at any point across the 40 in. of width where a weak packing of fibers might occur in the throat, a strong air flow is established and tufts are immediately pulled into the weak spot to build it up. Thus it is seen that we have a sensitive and reliable method of mat formation which has given outstanding lengthwise and widthwise uniformity and which has accomplished our objective in providing a satisfactory feed mat for the Rando-Webber where we did not find satisfaction with mill run picker laps.

Another advantage in this air-bridge, screen-box system is the constant dust cleaning that takes place. The partially opened cotton in the form of tufts is swept with an air flow as shown in Figure 2. In the mill the fan outlet would be connected to a dust box.

Upon advice from people who know cotton processing in the mill, a Model 40-B has been designed and manufactured. It was also necessary to obtain a more universal form of the Rando-Feeder for use with the Rando-Webber. The new features built into the Model 40-B as compared to Model 40 are an extended hopper with a floor apron and a stripper apron, which also returns excess stock to the rear of the hopper to prevent jamming at the elevating apron. The air-bridge, screen-belt principle has been maintained; however, the screen belt has been replaced with the 12-inch rotary condenser that is used in the Rando-Webber (see Figure 3).

Model 40-B Rando-Feeder has been on the test floor since January 1st and, while not all of the "bugs" of a new model have been worked out, preliminary performance data will be given which may prove interesting to cotton people.

The Rando-Feeder measures the output of fiber on a volumetric basis. It is done in the air bridge where the individual tufts are packed in under steady flow conditions. The packing pressure is dependent upon the intensity of the suction pressure existing in the screen box and is directly related to fan r.p.m.

Figure 4 shows a calibration curve for bale cotton.

Examination of this data, along with data taken in connection with other studies, shows the fine degree of response for weight of fiber output with change of fan r.p.m. when other variables are held constant.

It is natural to assume that controlling the surface speed of the screen in the screen box would be the most desired method of controlling the Rando-Feeder output, all other variables held constant.

In Figure 5 curve *A* represents the low range characteristics while curve *B* was taken when exploring high output capacities. Fan r.p.m. and floor apron travel have been stepped up as compared to curve *A*.

A comparison of the graphs of Figures 4 and 5 shows that two good methods of control of output are

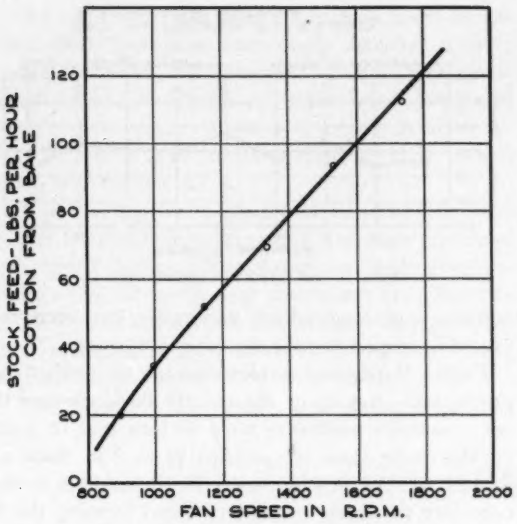

FIG. 4. *Output in lbs.* vs. *r.p.m. of fan.*

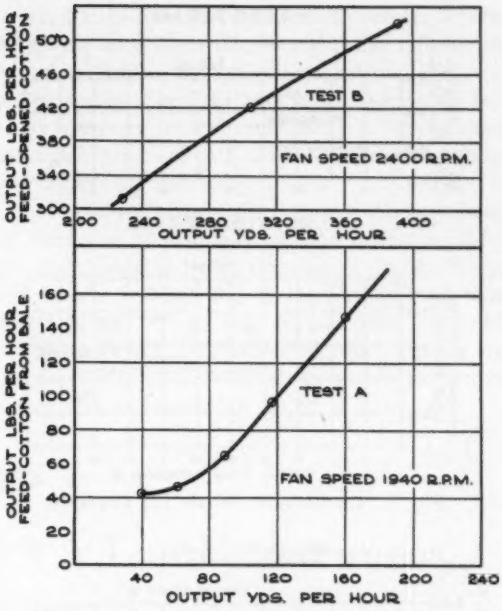

FIG. 5. *Output control by condenser r.p.m.*

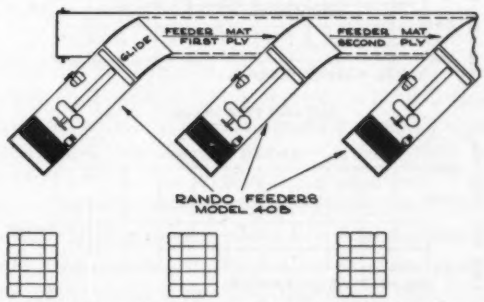

FIG. 6. *Suggested arrangement of Rando-Feeders to blending line.*

available. This means that the surface speed of the feeder screen might be driven by and synchronized with subsequent equipment, such as a cross conveyor, and the weight of fiber fed or processed per hour can be determined by the speed of the fan.

It has been shown that two separate control methods are available for changing and governing the pounds of fiber flow per hour delivered by the Rando-Feeder. It is suggested that these feeders might be used in the blending lines for cotton processing with a resulting improvement of the product of the mill.

A possible arrangement of equipment in this respect is shown diagrammatically in Figure 6.

The individual feeder mats delivered by the Rando-Feeders would in each case be the measured element of a desired blend of cotton or other fibers to be blended with cotton.

In the arrangement illustrated in Figure 6 a sandwich, which is a blend of the different bales of cotton or other fibers, as the case may be, is laid on the cross conveyor. Furthermore, the blend in such a sandwich is uniform depthwise, widthwise, and longitudinally, inch by inch and yard by yard, and there has been no reshuffling to even out batches as when weighing hoppers are used.

The condenser surface speed of the Rando-Feeder may be synchronized with the cross-conveyor belt by extending the drive of the cross conveyor to the condenser drive on each feeder. Any change in the cross-conveyor speed will change the output of each and all feeders per hour, but not change the blend ratio or the yard to yard weight traveling on the conveyor. In this manner the subsequent processing machines may receive varying input in pounds per hour by controlling the cross-conveyor surface speed. The blend ratio that was originally established will stay constant or may be revised by simply varying the speed of the individual feeders fan through the use of a hand wheel at the fan motor of each feeder in the line.

In proposing the system of blending, as outlined, it is necessary to establish the operating characteristics and the accuracy that can be obtained and maintained.

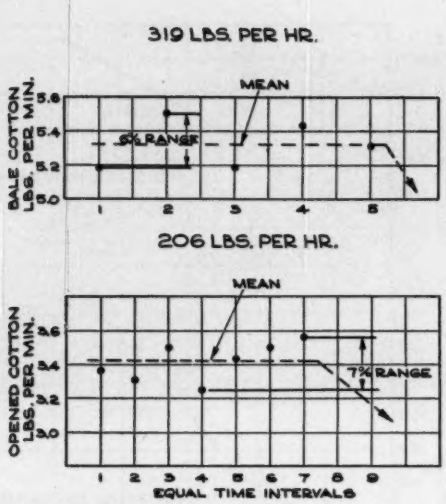

FIG. 7. *Output rate, hopper full to empty.*

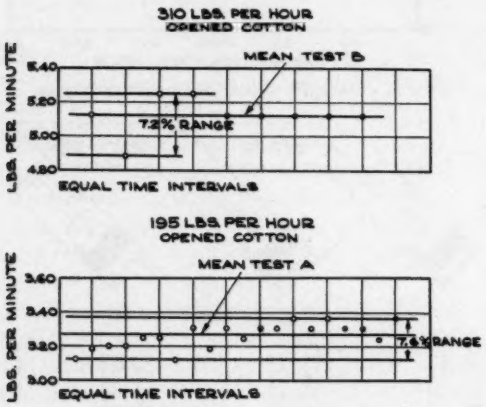

FIG. 8. *Constancy of output.*

A test for constancy of output during hopper withdrawal is shown in Figure 7. These tests show a practical use of hopper capacity and the net result is less attention on the part of the operator.

Figure 8 shows graphically the variation of output with all operating variables held constant. At fixed intervals the output of the feeder was collected for one minute and weighed. Curve *A* represents cotton that has been through the feeder once and rerun for the test. This, in effect, provides opened cotton for the test run. Curve *B* represents opened cotton ($1\frac{1}{32}$ in. Strict Low Middling from Marked Tree, Arkansas). It is noted that in both Figures 7 and 8 the points scatter within a range of $7\frac{1}{2}\%$ or the deviation becomes not greater than $\pm 3\frac{3}{4}\%$. This

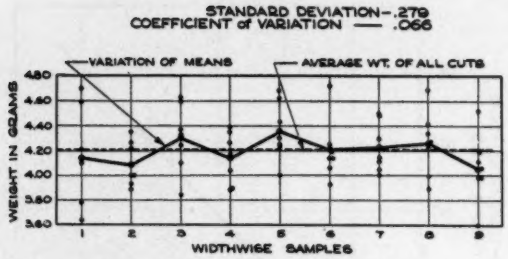

FIG. 9. *Widthwise uniformity.*

constancy of longitudinal uniformity has been repeated in respect to tests for other purposes.

Figure 9 requires explanation as to method of procedure. A 4 sq. in. die and die block are used to cut 9 samples widthwise on a 40-inch mat or web. As the feeder mats are perhaps $1\frac{1}{2}$ to 2 in. thick as formed and released by the feeder, it has been found necessary to clamp a template board locating the 9 die cuts over the mat while making the cuts. The procedure is to run a 40-inch sheet of paper under the mat while it moves forward on the conveyor; also to lay a shorter piece of paper on top of the mat and to cut off a 2-foot length of mat and transfer the whole to the die block. The template is clamped over the entire assembly of paper and mat. The cuts are made and the 4-inch squares of fiber are weighed to the nearest hundredth gram.

Feeder mats, when die cut without compressing under a template, show a relatively wide scatter of sample weights. The same mats, when somewhat compressed under the template, show much less scatter. We doubt whether the data shown is entirely free from adverse sampling and cutting procedure.

In a number of widthwise uniformity tests, in addition to those shown in Figure 9 and also including test runs on Dynel and blue acetate waste, the standard deviation has been .279 or less and the coefficient of variation under .066.

Experience and data gained from mill installations, along with laboratory tests, indicate performance superior in many respects to conventional processing. For instance, in one application where a blend of glass and asbestos fibers was processed through the combined Feeder and Webber we were required, as a matter of acceptance, to demonstrate in production runs a uniformity range of not over 10% of mean weight. In other words, no 4-inch die cut was to weigh more than 105% of mean nor less than 95% mean regardless of its position in the product web widthwise or lengthwise.

The air bridge and screen box have been in use since 1949 and have successfully handled a wide variety of fibers, for example, asbestos, glass, redwood bark, Spanish moss, sulfite wood pulp, and short carpet clippings all the way from $\frac{1}{8}$ in. and $\frac{1}{4}$ in. fiber length to 2 in. staple, including staple cotton, wool, and synthetics.

A pair of machines, Model 84 Rando-Feeder and Model 84 Rando-Webber, using the same principles was tested during the past summer with good results. The air-bridge and screen-box arrangements in the 40-inch and 84-inch Feeders have demonstrated their ability to form uniform mats widthwise and longitudinally from 40 to 84 in. in width.

The foregoing description and performance data for the Rando-Feeder, Model 40-B, present a new and unique method for the formation and delivery of fiber mats, which we believe are formed with increased accuracy both longitudinally and widthwise. Means are provided for establishing a blend at the bale which proceeds as a sandwich, uniform depthwise, widthwise, and longitudinally.

The cross conveyor with its sandwich may very well feed into an additional Rando-Feeder to complete the mixing of the components of the blend and to deliver a uniform mat of the blend to the first process picker. There may be additional points of application in the mill not mentioned. Testing on this model will continue in our laboratory to perfect performance and control of output.

Causes and Effects of Picker Lap Unevenness

Earl Heard, Jr.*

Tritex Corporation, Lanett, Alabama

MOST mill managers will agree that evenness of picker laps is important in the operation of the mill. However, they will generally add that they need new spinning, or have problems on their drawing, roving, slashers, or some other process. We feel that the importance of the picker lap is often underestimated.

Every mill manager is faced daily with the problem of maximum pounds at a given quality with minimum cost. A host of problems are constantly streaming across his desk, one of the most difficult, demanding of all his skill, judgment, and experience, being where shall the money be spent for new equipment, modernization, and improvement of the mill in order to obtain lower cost, better quality, and maximum production.

For this discussion let us set up a theoretical mill using Middling 1 in. cotton with a Micronaire fineness of 4.5 and a Pressley strength of 78,000 lbs. The pickers are making a 14-oz. lap, 56 yds. long, with a net weight of 48 lbs. We will assume a draft of 120 on the card, two processes of drawing, six ends up, each with a draft of six, one process of roving with a draft of ten, and spinning with a draft of twenty producing 20's yarn from one hank roving and making a 4-oz. package on the spinning frame.

In the present market, and probably from now on, quality is of paramount importance. Let us assume that the customers of this mill are complaining about quality, and that the mill manager is faced with the problem of what to do about the situation. First, with respect to his raw stock, we find that he is already using a good quality of cotton suitable for these yarn counts and that his cotton is under control. He knows from long experience that, if he runs double roving in the creel in the spinning frame, the doublings will give him some improvement. Let us take a look at what it will cost this particular mill to go to double roving in the creel on spinning, so that we might understand more clearly the incentive to make a better roving or to improve each process prior to spinning in order that the mill might stay on single creel roving. The difference in cost is obviously the cost of making a finer roving and the added cost of creeling.

A fair, average cost for double creel roving for spinning 20's will be 1 cent per pound more than the cost for spinning the 20's out of single creel roving. In a mill producing 100,000 lbs. of yarn per week this would be an added cost of $1,000.00 per week, so such a move should be scrutinized with extreme care before this added cost is put on the mill.

* President.

The first step in a mill operation, the control of cotton fiber properties and quality, has received a great deal of attention in the past few years due to new yardsticks being developed to measure fiber properties that have not been measured in the past. Many mills no longer buy their cotton on grade and staple alone, but use the Micronaire for fineness, the Pressley machine for fiber strength, the maturity test, and are fervently hoping for a test to identify overdried cotton, since preliminary tests following up the 17-Mill Tests certainly seem to indicate that overdried cotton is causing a great deal of trouble in the mills. Increasing pressure is being put on the cotton departments to furnish the mill raw material with consistent properties, and also opening rooms are being redesigned and new equipment installed in order to obtain the best possible opening, cleaning, and blending of the stock.

The next step is to take this raw material and make it into as uniform a yarn as possible. The problem of a definite and uniform weight per unit length is one that every mill man meets with daily in an effort to control yarn size, cloth appearance, and cloth weight. The picker is the first process in the mill where an attempt is made to control weight per unit length. The linear unevenness in a picker lap is overcome to some extent by means of doublings. We have shown in our theoretical mill what doublings cost at the spinning frame. The fact that the mill has been forced to go to fewer and fewer doublings quite naturally has increased the importance of each process with respect to the control of evenness, and this means that each and every process in the mill must be examined and re-examined critically from time to time to determine if there is any way by which that particular process can be improved.

In our study on pickers we have come to the conclusion that there are five factors which are important in a picker lap, and there are undoubtedly others with which we are not familiar and have no means of measuring. These factors are: (*1*) total lap weight variation, (*2*) yard to yard variation, (*3*) short term variation or within yard variation, (*4*) lateral variation or variation from selvage to selvage, and (*5*) the construction factor.

Total Lap Weight Variation

Every mill man knows that you cannot indiscriminately mix gin bales, standard density bales, and high density bales in a mix. The different densities of the stock play havoc with picker room lap weights. However, another cause of variation in stock density is an insufficient number of hoppers or blending feeders in the opening room and improper feeding of these machines. Good practice, with which we certainly agree, recommends the use of a minimum of two blender feeders per picker and preferably three. With two blender feeders per picker and the picker operating at a production of 300 lbs./hr. each blender feeder must deliver 150 lbs./hr. at 100% production. These blending feeders should run 85% to 90% of the time, and higher if possible, and should be fed on a patrol cycle in order that the hoppers will not run heavy and lean.

In order to get a higher production through a hopper or blender feeder it is necessary to set the combing roll further away from the lifting apron and large, very dense pieces of cotton pass on to the feed apron when the hopper is full; in the latter stages just before refilling, finer, less dense material is passed through to the feed apron. It is only natural for an operator, in an attempt to do the job with a minimum of effort, to fill the hopper as full as possible and let it run down as low as possible before refilling. It is obvious that this aggravates the condition referred to above. The blending reserve on the picker, if it is being used, cannot distinguish densities since it will hold the same volume of flat gin packed cotton as it will of high density pressed cotton. The evener motion on the picker, since it is a device or measuring thickness, cannot completely compe e for variations in density. Evener motions are designed to measure differences in thickness of material of the same density.

Total lap weight variation also results from the operator adjusting the evener motion from lap to lap to compensate for total lap weight variation. This is a long term adjustment and lap to lap adjusting actually results in more rejected laps. Of course reworkable waste, if not accurately controlled and blended constantly with the stock being fed to the pickers, will produce a tremendous variation in total lap weight.

Yard to Yard Variation

Yard to yard unevenness is caused by: poor condition of the evener motion; improper adjustment of the evener motion as to sensitivity; in the case of a picker with a blending reserve, improper setting of the rake for level control; improper high speed—

low speed feed to the blending reserve; or in the case of a picker without a blending reserve, improper feed to the picker itself. There have been some important improvements in evener motions in the past few years; however, it is still basically a crude mechanism. Recognizing this fact, it becomes highly important that the evener motion be given the best possible care. The measuring shoes should be kept clean and free on their fulcrums; the cone belt kept at the proper tension and clean to avoid slippage. Everything connected with the evener motion must be in excellent condition if it is to perform its function. The sensitivity of the evener motion must be correct. By sensitivity we mean the relation between the variation in thickness fed under the shoes to the speed change of the evener roll. As far as we know there is no method of easily calculating the sensitivity required and it must be arrived at by trial and error on each individual picker by changing the length of the fulcrum arm which actuates the belt shifting mechanism.

The effects of total lap weight variation and yard to yard variation in the picker lap are somewhat similar. Let us assume that we made a lap which is 2 lbs. heavier than standard, and that these 2 lbs. or 32 oz. of extra weight are distributed equally over the 56 yds. of the lap, making each yard weigh $\frac{3}{5}$ oz. heavy. Total draft in our theoretical mill from carding through spinning is 864,000; this means that our 56 yds. of heavy lap will be distributed in approximately 48 million yards of yarn. With 20's yarn having 16,800 yds./lb. and assuming a 4-oz. spinning bobbin, our heavy lap will be a portion of 11,520 bobbins of yarn. It can be seen that for long term control of yarn counts and cloth weight total lap weight variation is important.

One yard of picker lap in our theoretical mill would form a portion of only 206 bobbins of yarn instead of 11,520 bobbins formed by the entire heavy lap. However, it is becoming obvious that this is still extremely long term control of the finished yarn and does not correspond to any of the daily checks for yarn count control and control of cloth weights.

Within Yard Variation

In our early work it was found that by intensive work on the picker we could produce a lap with good yard to yard and total lap weight variation. However, when these laps were carded on the same card, which was in excellent condition, we found a wide disparity in the weight per yard variation of the card sliver from laps from different pickers. These facts led us to believe that there undoubtedly must be other factors in the picker lap which we had not been measuring which influenced tremendously the weight per yard variation of the card sliver.

With a draft of 100 to 120 on the card it is easily seen that $\frac{1}{8}$ in. of picker lap makes approximately one yard of card sliver. This $\frac{1}{8}$ in. of lap in our theoretical mill drafts to approximately $1\frac{1}{2}$ bobbins of yarn. At this stage of the game a faint light began to glow in the darkness, for we began to realize that the within yard or fraction of an inch variation in the picker lap was vitally important, and we began to concentrate our efforts in an attempt to improve this short term variation in the picker lap.

The first factor we studied was the Kirschner beater, since it is used primarily in the finisher sections of pickers. There seemed to be a large amount of turbulence present between the beater and the screen section of the picker, with cotton flying in every direction, eddy currents being formed, and little control of the air currents in this finisher section. Careful air flow measurements at various levels and across the entire width of the picker fully confirmed this fact. This is easily understood when you examine the construction of a Kirschner beater. In an effort to overcome this turbulent effect caused by the Kirschner beater we designed and built a solid cylindrical-type beater and tried practically every combination of pins of different types and different numbers of pins throughout the beater. Our present beater is a result of many, many trials with beaters of every conceivable type of construction and combination of pins.

The second phase in our attempt to secure a better within yard evenness was to examine the flow of air carrying the cotton from the beater to the screen. In a conventional picker the air is pulled through the grid bars under the beater and the stock is carried to the screens by this air current which in turn is being exhausted from the end of the screens, by a fan located in a housing underneath the picker, and delivered to the dust house or filters. While this air is being pulled through the openings between the grid bars, trash removal is being accomplished through the same area. Every mill man has at one time or another seen foreign matter being knocked out through the grid bars on a picker and then being sucked back up into the lower grid bars by the air

current. This is an obvious defect, so we installed a separate air intake tunnel, just in front of the grid bar section. In the early trials many, many different designs of air intake tunnels were made. We finally adopted one which extends 12 in. below the grid bar with a baffle plate dropping from the back of the tunnel down to the floor in the waste compartment, thus sealing off the air intake from the waste compartment and dividing this area into two sections; the back section under the grid bars receives the waste while the front section is for intake of air. These two steps—the building of the cylindrical type beater and the installation of the air tunnel—helped materially but did not give all the answers.

Lateral Variation

It was decided that in order to secure the best possible short term evenness there must be a rapid delivery of the stock to the screens, and there should be no hunting or shifting of the cotton as it hits the screen. The whole area from the beater to the screen section was redesigned, and many designs were tried before arriving at the proper area of the screen sections to be exposed. The design which was adopted involved a constriction in the channel between the beater and the screen section which increases the speed of stock movement. In our work it became readily apparent that exhaust conditions of the picker fan play a part in securing proper control of air currents, and we found that some types of air filters and even some dust houses with inadequate capacity were unsatisfactory.

Recently several companies developed lap meters for measuring short term variation in the picker lap. We certainly feel that any time a new measuring device, capable of measuring an important quality, is made available, progress is being made. The fact that these companies have spent a great deal of time and money to develop instruments of this nature is indicative of the importance of within yard variation. By improving the short term variation in the picker lap a definite improvement can be shown in card sliver weight per yard variation, since this variation is a function of total weight, yard to yard, and within yard variation of the picker lap. A corresponding improvement in drawing sliver weight per yard variation, hank variation in roving, and count variation in spinning will result.

Lateral variation in picker laps received very little attention. Sometimes it is difficult to get everyone in the textile industry to agree upon any one subject. However, I believe that we can obtain practically unanimous agreement on the matter of the rate of production of cards and its effect on quality. The lower the rate of production of the card, lbs./hr., the better the running condition of the mill and the higher the quality of the finished product. The card is designed primarily to perform one job, namely, that of fiber separation. However, it happens to be one of the best cleaning machines in the mill because of its low rate of production and the degree to which it opens the stock. It is the only place in a carded mill where fibers are placed upon wire and combed or brushed with other points of wire in order to get this fiber separation. Every subsequent process after carding in a carded mill is a drafting process whereby the sliver or roving is nipped between a set of rolls and is drafted out by another set of rolls. Good sound reasoning and long experience by men who have spent years in the textile industry lead us to believe that good drafting and better yarn can be made from the stock which has been thoroughly opened, and the previous reference to low card production fully confirms this statement. In the drafting zones following carding, fibers which have not been separated normally draft as a bunch or lump, which will cause a thick place in the yarn immediately followed by a thin place.

What is the correlation between fiber separation on the card with lateral variation in the picker lap? In a lap which we will use for illustration where the body of the lap has a light selvage followed by a heavy place and a light section in the middle followed by another heavy section with another light selvage, the card is in effect carding at different rates of production across the width of the card cylinder. In other words, in that section of the card cylinder which is receiving a heavy streak of picker lap there are more fibers per square inch on this section of the card wire at any given instant than at that area which is being fed a thin section of the lap. There is practically no shifting of fibers across the card cylinder; this can be proven very simply by stripping the card out completely and feeding a 4 in. wide strip of lap to the feed roll in the middle of the card cylinder. It can be readily seen that approximately a 4-in. strip of web appears at the same place on the doffer. We

have often had the question presented: "Well, what difference does it make? When the web comes off the doffer it passes immediately through a trumpet and the calender rolls and the stock is all combined together again in the sliver." Quite to the contrary, instead of leveling out this effect, such action penalizes the quality of the product because the resulting sliver has varying degrees of openness or fiber separation; in subsequent drafting zones this is going to create irregularities.

Causes of lateral variation are mainly lack of control of air currents in the finisher section of the picker, lateral variation present in the batt fed to the finisher beater, and improper balance between volume of air, amount of stock on the screens, and open area of the screens. The cleanliness of the picker —that is, freedom from chokes—also is important. Each picker seems to have "lateral characteristics" of its own and hence presents a different problem. In order to further improve lateral variation, the air intake tunnel, which was discussed earlier, was divided across the width of the picker into 10 compartments with each compartment having a separate door or gate at the intake section of the air tunnel. These gates were not incorporated in the original design and their influence and importance was discovered by chance. We were working on the picker one day and suddenly cotton started piling up toward the right-hand selvage on the screen section and we were quite puzzled as to the cause. At this time we were using a tunnel that extended all the way from the grid bars down to the floor and it was difficult to see into this tunnel with the beater in place. After examining the picker thoroughly in an effort to find out what was causing this heavy place on the right-hand selvage we checked down in the compartment of the tunnel on the right-hand side and found a small choke caused by a ball of cotton that you could very easily hold in the palm of your hand. This led us to realize that if a small choke in the tunnel could accomplish this shifting of fiber, a gate or damper should perform the same function. We then made gates for each segment of the tunnel which can be adjusted to any desired opening. By controlling air coming in through any one of these compartments in the tunnel we can shift the cotton at will on the screens and in this manner maintain a lap uniform from selvage to selvage.

Construction Factor

The fifth quality feature is a relatively intangible item, which we will call a "construction factor," which is a combination of the degree of openness of the fibers, the cleanliness of the stock, and the way the fibers are formed on the screen section.

What does a card tender want in a picker lap? He wants those factors in a lap which will make his job easier, quite naturally. Therefore he wants a lap of just as hard construction as he can possibly get, a lap that can be handled satisfactorily, one that will unroll on the cards without splitting, but more than that he wants a lap that will produce good card sliver. Therefore we believe that a lap should be just as light and fluffy as it can possibly be with only two limiting factors: (*1*) Will it split on the card? (*2*) Can it be handled using only reasonable care, without creating an excessive amount of waste?

Every mill man has at one time or another seen a lap coming off a picker which had a rough look which we call nubbiness. A lap of this type with small bunches or clumps of fibers tangled together is not, in our opinion, the best lap to be presented to a card. Generally these tangled clumps of fiber are caused primarily by the fact that there has been improper opening in the picker itself and, in all probability, equally as many because the turbulence present in the finisher section of the conventional picker, the rolling, tumbling, and lagging action of the air currents which form the cotton on the screen section, is conducive to such a condition. These clumps of fibers in combination with the existing lateral variation on the picker, in our opinion, are a principal cause of plucking at the card.

Total lap weight variation, yard to yard variation, short term or within yard variation, lateral variation, and the construction factor are all important in producing a good picker lap that will make good card sliver. The role the picker plays is becoming increasingly important as new processes are being developed to cut operating cost and as doublings are further reduced. Not so many years ago it was practically impossible to detect the effect of picker lap unevenness in subsequent processes and in finished yarn. However, in this age of quality control and statistical analysis it can, has, and is being proven daily that the picker lap plays a major role in yarn manufacture.

Mill Application of the Tritex Picker Attachment

J. L. Delany

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ON the standard picker the sheet of cotton passes through the feed rolls and is struck repeatedly by the beater. The cotton is then carried forward by the air stream and is deposited on the screens. When the picker lap is too heavy or too light on either side, corrective adjustment is made. The air admitted is controlled by adjusting the dampers in either side of the picker cage section. This procedure, however, does not allow very much control; there is either too much or too little air, and often too frequent adjustment of controls is necessary.

Air entering the picker comes in under the beater, and passes through the grid bars, through the beater, and on to the screens. Here, then, are three separate points where the uneven distribution of the air can contribute to unevenness of the lap. First, the air going into the beaters through the grid bars is an abomination. At this point the beater knocks out trash, fly, and foreign matter, and then sucks it back into the air stream. Second, the air passing through the arms of the beaters creates a turbulence which seriously affects the uniform sheeting of the lap. Third, the dampers located in the air trunks of the picker give only meager control of the lapsheet, and are obviously expected to do a bigger job than they are capable of doing.

The Tritex finisher beater section has been redesigned to take care of these three deficiencies. The beater waste box was split by a partition, and a 40 in. × 8 in. wide duct compartmented into eight sections was fitted into the forward section. Each of the eight duct compartments was fitted with its own damper in order to obtain uniform lateral control. The part immediately under the grid bars was thus blocked off to become a dead-air section. The forward part of the beater waste box was left open to feed fresh, clean air into the compartmented duct. This modification, then, did away with sucking lint and fly back into the picker through the grid bars. The second problem—turbulence in the beater causing bad sheeting—was overcome by the addition of fill-in pieces to the Kirschner beater, which converted it into a cylindrical, lagged beater. The lags were replaced by a new lag containing pins with blunt points. The sides of the beater box were fitted with steel fill-in plates to give closer air control.

With the air coming into the picker in regulated quantities, with turbulence in the beater box minimized, and with no trash pulled back into the machine from the grid bar section, it was felt that much had been done toward making the ideal lap.

One point brought out by the Tritex salesman is that a variable rate of carding takes place across the width of the lap at the card—for example, in the case of a lap having extended thin places and adjoining thick places, all in the longitudinal direction, if the job is set up to card 8 lbs./hr., it is possible that the card would produce at a rate of 4 lbs./hr. on the thin place and 12 lbs./hr. on the thick place. There might also be a certain amount of "plucking"—that is, thin spots pulled through the feed rolls by the licker-in while the feed roll is somewhat elevated by a thick place in the lap. Either of these defects will seriously affect the quality of the sliver produced.

This company became interested in the Tritex attachment because there was too much lateral and longitudinal variation in its picker laps. It was felt that if it were possible to make a more even lap, there would be a corresponding gain in successive processes following the picker. Besides a reduction in lap variation, better, more even card sliver with less neps should be made. Ultimately, there should be less ends down in the spinning room plus a stronger, more even yarn.

Did Joanna get what it wanted? No, we didn't get it all. What we did get was a more uniform lap in the lateral direction. Lap tests were made by placing the lap on a long table, unwinding several yards, and, by using a template, cutting this unwound lap into 4-in. strips 36 in. long. Four full yards were cut into strips and weighed individually. The test was run on a standard picker as well as on the Tritex-equipped picker. It was found on a very long series of tests that the regular picker's lateral variation averaged 15.0%, while the Tritex averaged 6% to 8%. This was a gain which had been hoped for,

and it was felt that all our expectations would be satisfied.

Neps.—We looked very hard for an improvement in neps, and, after a long series of tests, the following results were found: The regular picker produced at 38.8 neps per 100 sq. in., and the Tritex produced at 39.4 neps per 100 sq. in. There was no improvement.

Ends down.—It was then decided to channel enough stock into spinning to check for end breakage and yarn strength. The result of the first test on end breakage was excellent. This result was twice as good as that obtained on the regular picker. We ran a second test which broke even—no gain, no loss. In a third test, another drop was shown in end breakage. Although the drop in end breakage was not as great as in the first test, the improvement was significant. On still another test, there was a break-even result. To sum up the above results, Tritex produced 25 ends down *vs.* 30 ends down on the regular picker. However, there was no great difference on about a 30,000 spindle-hour test.

Variation.—Tests on the Brush analyzer showed 117 on the regular picker as against 114 on the Tritex. Break factor on the regular picker was 1936, as against 1943 on the Tritex.

We had checked just about everything, and had come up thus far with only slight improvement. Superficially, the attachment looked good, and we were convinced that the Tritex device must have superiority due to its very nature. Everything pointed to improvement quality-wise, but it was obvious that we needed additional proof.

At Joanna there are three spinning rooms, called Mill One, Mill Two, and Mill Three. For some unknown reason, Mill One had always shown a higher breaking strength than Mill Two. Top management suggested one way to settle the problem. Enough stock was to be channeled into Mill Two to cover it fully, and this was to be done for several months. One unit of Tritex was not sufficient to do the job, and therefore two more units were installed. All Tritex stock was channeled to Mill Two, and a graphic record of all results was kept.

As can be seen in Figure 1, there was a lower break factor in Mill Two than in Mill One during the 22 weeks before the test took place. The dramatic reversal in higher count-strength constant which occurred coincidentally with the impact of the Tritex-processed stock is something to observe. As may be seen, the break factor of both mills took a rise, but Mill Two got out in front and remained there during the 18 weeks of the check.

We then decided to install Tritex 100% in the picker room; therefore, the test was discontinued. Later, as both mills were fed from Tritex-made stock, the break factor in Mill One again came to the fore. This was thought to be due to the refrigerated air-conditioning system.

At Joanna it is felt that the Tritex picker device aids in making a really good picker lap, and that by holding to a very rigid maintenance schedule, it is possible to realize the potentialities of the attachment.

The picker is a big, bulky, high-production machine. It needs a great deal of constant attention. Formerly we had depended on tearing down the pickers every 4 months for an overhaul. Thorough cleaning, checking leathers and replacing them when necessary, checking bearings and gears, and generally giving the machine a good going-over was necessary. Therefore, ordinary maintenance was depended on to keep up the job until the picker was overhauled again. One would think that with a good lubrication and cleaning schedule the job would run smoothly and give no trouble. That idea is entirely false!

Since the picker operates in a rather dusty atmosphere, with so many belts to stretch, go slack, get dirty, and quit pulling, and with so many slides to stick, gear teeth to foul-up and break, bearings to get stuck from entrained dirt in the oil or from no oil at all due to plugged oil holes, the tremendous prob-

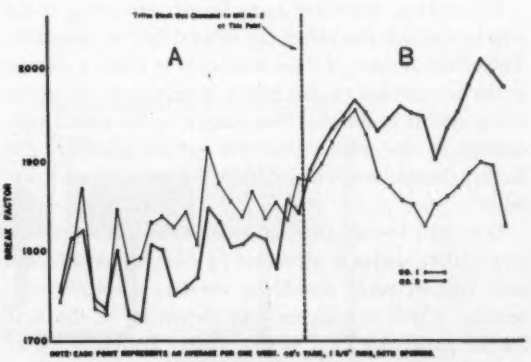

FIG. 1. *Comparison of break factor in two spinning rooms at Joanna Cotton Mills.* A—*Both Mill One and Mill Two fed with cotton processed on standard beaters.* B—*Mill Two fed with stock processed on Tritex picker attachment.*

lem of maintenance is obvious. Joanna has tried to solve this problem by maintaining a check-sheet type of program, where the fixer is required to check a certain number of picker items per shift. The assistant overseer then double checks. The check sheet is signed and returned to the general overseer, who looks over the sheet and puts it on file. The overseer also spot checks to insure compliance. In this way the attempt is made to minimize the possibility of a part or assembly going wrong and making bad laps before the picker breaks down or is caught in a periodic test.

Under present-day, "no-doubling" operations, the mill runs almost directly from the picker room, and therefore no pains should be spared to make as perfect a lap as is possible.

The Control of Size Take-Up in Slashing

The Shirley Automatic Size Box

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Abstract

The Shirley Automatic Size Box enables the percentage of size put on any warp to be controlled at any value, irrespective of variations which occur in the take-up characteristics of the warp, the physical properties of the size, or the mechanical conditions imposed by the machine. This paper, as well as describing clearly the principle of the box, develops a simple mathematical analysis of the regulating system and shows how various factors affect its response rate. Good agreement is shown to exist between theoretical and observed response curves. The essential features of the components of the production model of the box are described in some detail, and some of the advantages to be expected from using the box correctly under industrial conditions are discussed briefly.

Introduction

In slashing, there are many factors operating at the size box which can affect the weavability of the warp. The effect of most of these factors is to cause a change in the percentage of size which is being put on to the warp, and it is usually this change in the added percentage of size, rather than the specific effects of the factors themselves, which causes differences in weavability.

It is well known that, in order to ensure optimum weavability under a given set of weaving conditions, each type of warp should be sized to a certain percentage which experience has shown to be the best for the particular kind of size used. Provided, however, that this optimum percentage of size is obtained, the conditions operating at the size box, such as the viscosity of the size or the pressure at the nip of the squeezing rollers, can be varied over a very wide range without affecting weavability.

Therefore, in slashing it is very important to be able to control, at a specified value, the percentage of size added to the warp. In ordinary sizing practice, however, the achievement of such control has always been very difficult, if not impossible, because of the many factors affecting take-up which inevitably vary from beam to beam and from set to set. Another difficulty has been the absence of any really reliable means of knowing, at the time of sizing, how much size is actually going on to the warp.

The Shirley Automatic Size Box

The introduction of the system of automatic size regulation, developed by the British Cotton Industry Research Association at the Shirley Institute and now embodied in what is known as the Shirley Automatic Size Box,* has solved these problems; it is

* British Patent No. 654,178; U. S. Patent No. 2,583,267.

now possible to size any warp precisely to any specified percentage, even when the properties of the sizing paste, the conditions imposed by the sizing machine, and the take-up characteristics of the warp itself are unknown or varying. In fact, control can now be achieved simply by setting a pointer to the appropriate graduation on a dial calibrated directly in size percentage.

Basic Mechanism and Principle of Operation

In slasher sizing and similar continuous processes in which a moving sheet of material is impregnated with a substance by passing it through a bath containing a solution or suspension of the substance, the amount of the substance taken up by a given weight of the moving material depends, other factors remaining unchanged, on the concentration of the substance in the impregnating solution. Moreover, in practically all of these processes, a change in concentration in a given direction causes a change, in the same direction, in the amount of substance taken up. In sizing, it is therefore theoretically possible to put any percentage of size on any warp by adjusting the size concentration to the appropriate value. The control system described here maintains any specified percentage of size on the warp by automatically adjusting the concentration of the size to compensate continuously for all sizing variables.

Before considering the principle of this method of control, a brief description of the basic mechanism involved should be helpful. This mechanism is illustrated in Figure 1.

First of all, it is necessary to prepare a stock size which is sufficiently concentrated so that for the highest percentage of size which it is desired shall be put on the warp, some dilution of the stock size will be necessary after it enters the box. Also, the concentration of the stock size must be known—in fact, the stock size must be made up to contain a specified weight of sizing ingredients (starch, tallow, etc.) per gallon. This stock size is fed to the box by a metering pump of a type which always delivers precisely the same volume of size per stroke. This pump is effectively driven from the roller shaft of the machine through a gear system which enables the ratio of its speed of rotation to that of the shaft to be set to any required value. This ratio is so chosen that, while 100 lbs. of warp pass between the squeezing rollers, the weight in pounds of sizing ingredients which enters the box in the form of concentrated stock size is equal to the percentage of size wanted on the warp. It is obvious that, when using a stock size of a given concentration, the speed ratio for a fixed roller diameter will depend upon two factors only: the percentage of size wanted on the warp and the weight of a given length of unsized warp. The ratio will be directly proportional to both of these factors, and, consequently, the gear system can conveniently consist of two continuously adjustable gearboxes working "in series," as shown. The control knob on one gearbox is calibrated directly in the percentage of size required on the warp, and the control knob on the other gearbox, in the weight of dry unsized yarn per unit length of warp, or similar quantity, applica-

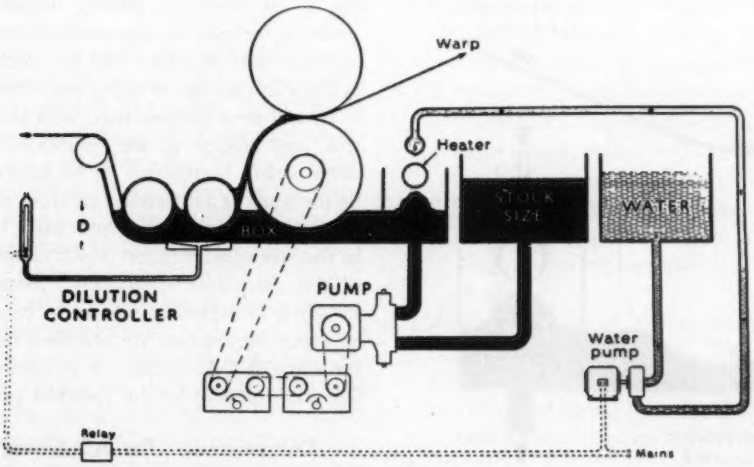

FIG. 1

ble to the particular warp being sized. The correct amount of dilution of the size at the box is dictated by the dilution controller. This device is, in effect, a very sensitive form of level controller. Whenever it detects a fall in the working depth, D, of the size in the box, it operates a relay which switches on the water pump. This pump draws water from a tank and sprays it over a heater into the box until the working depth of size is restored.

Basically, this is all that has to be done to effect control. The principle of operation of the system can be explained by reference to the more simplified diagram in Figure 2.

In order to understand the principle, it is necessary to keep in mind the following points:

(*1*) The controls are set so that sizing ingredients are always being metered to the box at the rate at which it is desired they should be taken up by the moving warp.

(*2*) The stock size containing these ingredients is always more concentrated than is required to put the desired percentage of size on the warp.

(*3*) Water is being run into the box and mixed with the size to maintain a constant volume * of size in the box.

* Actually, the particular kind of level controller employed maintains a constant weight of size in the box rather than a constant volume, but it is immaterial to the argument which of these quantities is considered; a constant volume is probably more easily visualized.

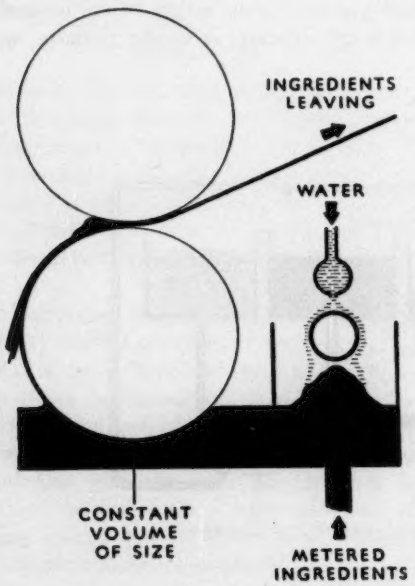

FIG. 2

(*4*) Ingredients can leave the box only by being taken up by the warp.

(*5*) Any rise in concentration of the size in the box brings about an increase in the percentage of sizing ingredients going on to the warp, and any fall in size concentration brings about a decrease in the percentage of sizing ingredients going on to the warp.

In order to illustrate the way the system works, let us see how it sets about adjusting the concentration if, at some time during running, the sizing conditions become such that a little more than the specified percentage of sizing ingredients is being taken up by the warp. This means that sizing ingredients are leaving the box at a slightly greater rate than that at which they are being metered to it. Consequently, the net weight of ingredients in the box is decreasing. The inflowing water is, however, maintaining a constant volume of size in the box, and so this decreased weight of ingredients is distributed in the same volume of size as before. The concentration of the size in the box is therefore falling. This brings about a reduction in the percentage of sizing ingredients taken up by the warp. It is obvious that this fall in concentration must continue until it has just counteracted the excessive take-up of ingredients by the warp. No further fall can then take place, because ingredients are leaving the box at precisely the same rate as that at which they are entering it through the metering pump.

By a similar argument, it could be shown that if conditions were to change so that less than the specified percentage of sizing ingredients was being taken up by the warp, this change would immediately initiate an increase in size concentration, which would continue until its effect had just counteracted the deficiency in take-up of sizing ingredients by the warp.

In will thus be seen that, with this system of control, any change in the conditions which tends to cause sizing ingredients to be taken out of the box by the warp at a different rate from that at which they are being metered to it immediately initiates a change in the size concentration which counteracts the effect of the change in conditions. Because the rate of metering of ingredients is set to be equal to the rate at which ingredients are specified to be taken up by the warp, it follows that the system will always force the warp to take up the specified percentage of size.

Compensation for All Sizing Variables

In developing the above argument, none of the factors which affects the percentage of size taken up

by the warp was specified. Included in these factors are the take-up characteristics of the warp, the physical properties of the size, such as its viscosity, and the mechanical conditions imposed by the machine, such as the pressure at the nip of the squeezing rollers. The reason for not specifying any of these factors is that they are not relevant to the argument, because the box automatically allows for them all by adjusting the size concentration to that required for putting on the desired percentage of size under the conditions prevailing at the time.

The box works just as well with a new type of warp as with a routine type, and the accuracy of control is unaffected by such factors as the type of fiber, the amount of twist in the yarn, or its moisture content. For example, if two warps which are otherwise similar differ in the amount of twist inserted in spinning, the warp of higher twist will, under a given set of sizing conditions, take up less sizing paste than the warp of lower twist. In ordinary sizing practice, this would cause a lower percentage of size to be put on the more highly twisted warp. When the automatic size box is set to put the same percentage of size on two such warps, the size concentration automatically adjusts itself so that, in spite of the different percentages of sizing paste taken up by the two warps, the percentages of sizing ingredients taken up are the same.

Typical physical properties of the size which can be fully compensated for by the box are its viscosity and temperature, both of which, in ordinary sizing practice, have a considerable effect on take-up. Thus, suppose that, with the dial set to put a certain percentage of size on the warp, the stock size was suddenly changed from one made from a highly viscous starch, such as farina, to one of equal concentration but prepared from a thin-boiling starch. This change would cause a gradual falling off in viscosity of the size in the box, the immediate effect of which would be a reduction in take-up of ingredients by the warp. This reduction would, however, bring about an increase in the size concentration which would very soon compensate for the effect of the fall in viscosity on take-up, so that the warp would again become sized to the target percentage. It is also obvious that the control system will deal with abnormal dilution at the box due to condensate from the steam used in boiling, the effect being balanced out by a reduction in the amount of water added by the dilution controller to maintain the size in the box at a constant volume.

As regards the factors affecting the take-up imposed by the machine itself, the most important of these are the pressure at the nip, the nature of the roller covering, and the speed of running. For example, if the pressure at the nip were suddenly increased, the first effect would be that the rate of removal of ingredients from the box by the warp would be reduced. This would cause a rise in the concentration of the size which would just compensate for the effect of the increased pressure on take-up. Sizing to the target percentage would thus be restored.

Mathematical Considerations

The action of the control system can be investigated mathematically. Such an investigation enables a clearer picture to be obtained of the way the system operates under different conditions and indicates some of the features essential to the design of a practical size regulator.

As demonstrated later in the paper, good agreement has been obtained between the theoretical and observed response of the system.

A brief analysis of the method of control will now be made before proceeding to a general account of the equipment as designed for industrial use. Definitions of symbols follow.

P = Weight of sizing paste or liquor in box. This weight is kept constant by adding water as required.

S_r = Weight * of sizing ingredients required per unit weight of warp.

W = Weight * of unsized warp sheet per unit length.

V = Speed of passage of warp through the box. This is assumed to be constant.

t = Period of running under investigation.

C_o = Weight of sizing ingredients per unit weight of paste in box when $t = 0$. This is a measure of the size concentration at the start of the run.

C_r = Weight of sizing ingredients required per unit weight of paste in box to put the required weight of sizing ingredients, S_r, on unit weight of warp.

c = Weight of sizing ingredients per unit weight of paste in box at time t. This is a measure of the size concentration at time t.

s = Weight of sizing ingredients being taken up by unit weight of warp at time t.

* Any weight referred to, except that of the sizing paste, is assumed to be the weight of the oven-dry material.

w = Weight of warp (excluding added weight of size) which has passed through box during period t.

We assume that there is a relation between s and c, called the take-up equation, which will first be written in the functional form $s = f(c)$. Later, the performance of the system for typical types of take-up equations met with in practice will be considered.

We shall also assume that the same take-up equation applies throughout the period t. The start of this period (*i.e.*, when $t = 0$) is considered to coincide with the initiation of a set of sizing conditions for which the concentration C_o is, in general, different from the concentration C_r required to put the target weight S_r of sizing ingredients on unit weight of warp.

In any time interval, the net increase in weight of ingredients in the box is equal to the difference between the weight of ingredients pumped into the box and the weight of ingredients removed by the warp.

Expressing this in terms of the above symbols for an interval of time dt, we get

$$Pdc = \{VWS_r - VW \cdot f(c)\}dt, \qquad (1)$$

or

$$dt = \frac{P}{VW} \cdot \frac{dc}{S_r - f(c)}. \qquad (2)$$

Integrating over a time t for which the concentration changes from C_o to c, we get

$$t = \frac{P}{VW} \int_{C_o}^{c} \frac{dc}{S_r - f(c)}. \qquad (3)$$

This shows that the time to change the concentration by a given amount is proportional to P, the weight of paste in the box, and inversely proportional to the running speed and the weight of unit length of warp sheet. As these last two factors are fixed by the process requirements and by the kind of warp, it follows that, in order to obtain as rapid a response as possible, the amount of size in the box must be as small as possible—*i.e.*, the box should have as small a capacity as possible.

When, in equation (3), $f(c) = S_r$, this is the final equilibrium stage and t is then infinite. This means there is an asymptotic approach to the equilibrium condition.

The rate of change of concentration with time is expressed by the equation

$$\frac{dc}{dt} = \frac{VW}{P} \{S_r - f(c)\}, \qquad (4)$$

in which VW/P is always positive. It follows, therefore, that the rate of change of concentration is positive when $f(c)$ is less than S_r and negative when $f(c)$ is greater than S_r. This means that the concentration is increasing when the take-up of ingredients by the warp is below the required amount, and decreasing when the take-up is above the required amount. The controller will therefore always adjust the concentration to correct for any change in take-up, provided an increase in concentration always causes an increase in the take-up of ingredients by the warp—*i.e.*, provided ds/dc in the take-up equation is always positive.

The response of the system is slower, the lower the value of ds/dc, and becomes infinitely sluggish when ds/dc is zero—*i.e.*, when the take-up of ingredients is unaffected by the concentration. (In ordinary slasher sizing, ds/dc has always been found to be positive, and its value is generally greater than 0.3.)

The product VWt is the weight of warp, w, which has already passed through the box at the time t We can therefore write equation (3) in the form

$$w = P \int_{C_o}^{c} \frac{dc}{S_r - f(c)}, \qquad (5)$$

which shows that t, as such, can be eliminated from the equation, and the approach to equilibrium can be expressed in terms of the weight of warp which has passed through the box.

The shape of the curve showing the approach to equilibrium will, of course, depend upon the take-up function.

The simplest take-up equation which is ever likely to apply is

$$s = kc, \qquad (6)$$

in which the take-up of ingredients by the warp is proportional to the concentration of ingredients in the box. This law holds approximately when sizing with very thin-boiling starches. If in equation (5) we write $S_r = kC_r$ and $f(c) = kc$, we get

$$-\frac{wk}{P} = \int_{C_o}^{c} \frac{dc}{c - C_r}. \qquad (7)$$

This equation yields

$$e^{-wk/P} = \frac{C_r - c}{C_r - C_o}. \qquad (8)$$

The right-hand side of equation (8) is equal to the ratio of the deviation in the concentration from the

required value C_r after sizing a weight of warp w to the deviation before sizing a weight of warp w.

If in equation (8) we put $w = P/k$, w is the weight of warp which has to pass through the box in order to reduce the deviation in concentration to $1/e$ (*i.e.*, approximately 0.37) of its initial deviation. This might be termed the "warp-weight constant" of the system because it is somewhat similar to the "time constant" in charging an electrical condenser.

The constant is a measure of the sluggishness of response of the system. It is proportional to the box capacity and decreases as k (*i.e.*, ds/dc) increases.

The analysis given above for the response of the system when the take-up equation is linear is also applicable when the controller is operating over any small portion of any curve showing the relation between c and s. This is a condition of operation which usually obtains in practice. If we assume, as is reasonable, that the small portion of the curve is a straight line, the "warp-weight constant" is then equal to P divided by the gradient, ds/dc, of this line.

As the take-up function becomes more complicated, the approach to equilibrium becomes more difficult to calculate. Fortunately, calculations can be made for a type of function which can be fitted with reasonable accuracy to most sizing take-up data. This is the parabolic form

$$s = \alpha c^2 + \beta c. \tag{9}$$

The equation implies an increasing gradient as the concentration is increased. This occurs because there is an increase in take-up of sizing paste as the viscosity increases with increase in concentration. When this function is substituted for $f(c)$ in equation (5), the approach to equilibrium is given by

$$w = -P \int_{C_o}^{c} \frac{dc}{\alpha c^2 + \beta c - S_r}, \tag{10}$$

which yields the equation

$$w = -P \left[\frac{1}{\sqrt{\beta^2 + 4\alpha S_r}} \times \log_e \frac{2\alpha c + \beta - \sqrt{\beta^2 + 4\alpha S_r}}{2\alpha c + \beta + \sqrt{\beta^2 + 4\alpha S_r}} \right]_{C_o}^{c} \tag{11}$$

This gives the value of w at any value of c between C_o and C_r. The value of s corresponding to any value of c can be calculated from the take-up equation (9), and thus the relation of w and s can also be found.

Equations (9) and (11) have been used to work out the approach curve for a particular work for which the values of α and β, when using a certain kind of size, had been experimentally determined and found to be 18.5 and 0.35, respectively. The take-up curve is illustrated in Figure 3. In Figure 4 the calculated approach to equilibrium for both the size concentration and the percentage of size on the warp is shown graphically for a target percentage of size of 10%, obtained when the size concentration was approximately 6.4% by weight. The box had a capacity of 7 imperial gallons.

The curves show the approach both from zero concentration (*i.e.*, commencing with water only in the box) and from an initial concentration calculated to put twice the desired percentage of size on the warp.

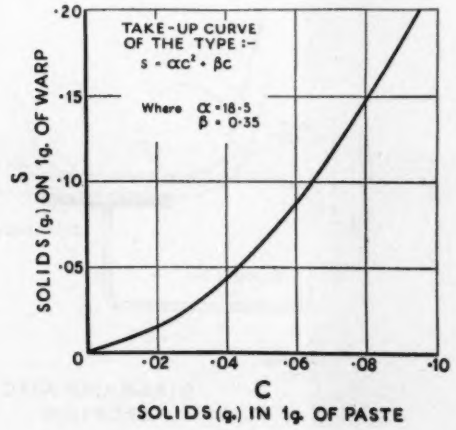

FIG. 3

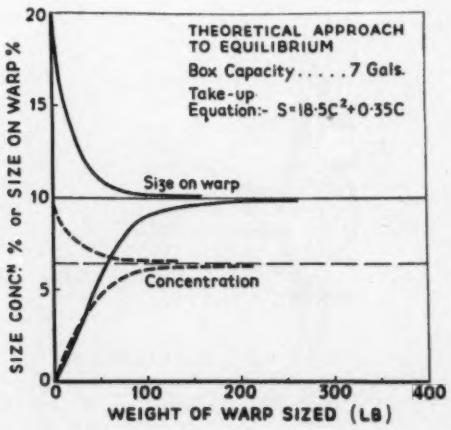

FIG. 4

An interesting feature of these curves is the higher rate of approach to equilibrium when the initial error is above rather than below the target percentage. This is due, of course, to the steeper gradient in the take-up curve when the concentration is high.

Take-up equations are based on take-up data determined experimentally. Although they are empirical, they incorporate the combined effects of the take-up characteristics of the warp, the size properties, and the machine conditions on the relation between size concentration and the take-up of sizing ingredients by the warp. Although these factors can cause differences in the rate of approach to equilibrium, they do not affect the level of control which is always at the target percentage.

Essential Design Features

It will be clear from the above discussion, and from other considerations, that for accurate control and ease of use, the automatic size box must embody the following features: (*1*) a box of small capacity; (*2*) an efficient method of intermixing the inflowing concentrated stock size, the water for diluting the size, and the working mixture in the box; (*3*) a device for accurately metering the stock size to the box; (*4*) simple means for setting the metering rate for different specified percentages of size and for different weights of warp per unit length; and (*5*) a method of controlling the inflow of water for diluting the size, so that the volume or weight of size in the box is kept constant to within very close limits.

Requirements (*3*) and (*5*) are met by the size metering pump and the dilution controller, devices which are described below. The methods adopted for meeting the other requirements are described in the section dealing with the production model (p. 570).

Size Metering Pump

A pump was required which would deliver, for each revolution, a volume of stock size mixing which remained practically constant irrespective of wide variations in suction and delivery head, speed of running, and size viscosity. In addition, it was essential that cavitation would not occur at temperatures as high as 200°F, and that any air reaching the pump would not collect inside it. These conditions were met by the use of a special form of plunger pump (shown diagrammatically in Figure 5). The plunger is operated by a cam, incorporating a "dwell" period at each end of the stroke so that the valves can be operated while the plunger is at rest.* This arrangement overcomes the difficulty, inherent in the usual reciprocating plunger pump, of both valves being open together for a short period, during which time unmetered flow of liquid can take place through the pump in one direction or the other, the amount of flow depending on such factors as viscosity and head of liquid. The pump has a volumetric efficiency of 100% throughout the full range of working conditions.

Dilution Controller

The function of the dilution controller is to turn on the water supply to dilute the size whenever the depth

* British Patent No. 676,137.

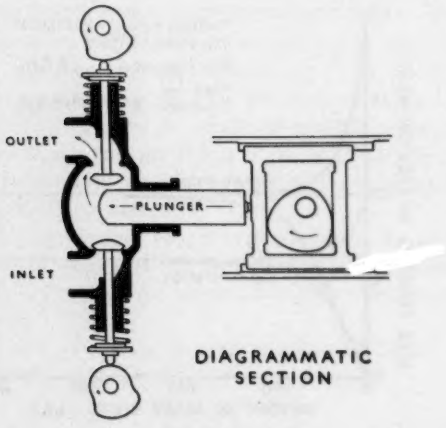

FIG. 5

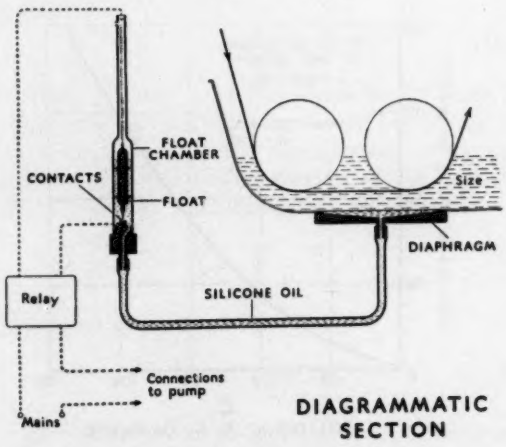

FIG. 6

of size in the box falls below the prescribed working depth. If appreciable fluctuations in size concentration are to be avoided when the water runs into the size, the controller must be able to detect a change in level no greater than that corresponding to a change of about one-fiftieth in the volume of size in the box. Also, the controller must work equally satisfactorily in both very viscous and very fluid mixings, which may be boiling and in a state of turbulence due to the rotation of the squeezing rollers.

The dilution controller is, in effect, a level controller, the essential features of which are illustrated in Figure 6. A shallow vessel, covered with a thin metal diaphragm about 6 in. in diameter, is fixed in the bottom of the size box. A flexible U-tube connects the outlet at the bottom of the vessel to a chamber containing a float. The diaphragm vessel, tube, and float-chamber are filled with low-viscosity silicone fluid in such a quantity that, when the size in the box is at its working depth, the diaphragm is in a relaxed state. Under these conditions, the hydrostatic head due to the size pressing downwards on the top face of the diaphragm balances that due to the silicone fluid in the float-chamber and tube pressing upwards on the lower face of the diaphragm. Because the cross-sectional area of the float-chamber is a small fraction of the surface area of the diaphragm, a very small movement of the diaphragm causes a considerable change in height of the liquid in the float-chamber. But such small movements of the diaphragm take place without the diaphragm itself applying any appreciable pressure to either the silicone fluid below it or the size above it. Consequently, over a limited range of depth change in the size, the system works, hydrostatically, very much as though the diaphragm were absent, and the depth of the silicone fluid in the float-chamber follows changes in depth of size in the box. The diaphragm serves to separate the viscous, sticky size (which obviously could not be used in the float-chamber) from the silicone fluid, which has been chosen for its ideal properties as a float-chamber fluid. The float has projecting lugs which act as guides to keep it centrally placed within the float-chamber. There is a carbon pencil electrode at the bottom of the float and a carbon block electrode fixed to the bottom of the float chamber. Whenever the level of size in the box falls, there is a corresponding fall in the level of the silicone fluid in the float chamber. This causes the float to fall and brings the two electrodes into contact. When contact is made, a relay is brought into operation which switches on a pump, which, in turn, sprays water into the box until the level of size is restored to its working level. A level controller of this kind will easily respond to a change in level of one-fiftieth of an inch, corresponding to a change in volume of size in the box of about half a pint. The controller works just as well with a very viscous size

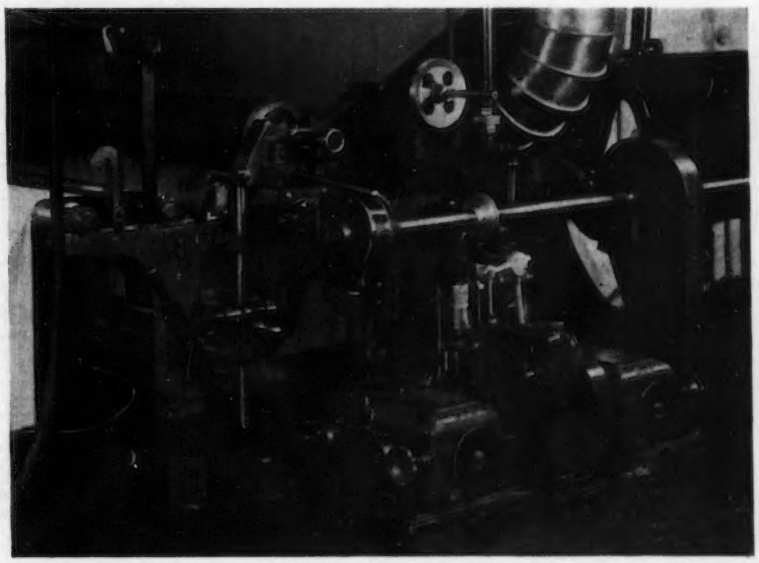

FIG. 7. *The Hibbert production model of the Shirley Automatic Size Box.*

as with a thin size, and its accuracy of operation is not affected by boiling and stirring the size. The diaphragm is treated with a special lacquer to protect it against corrosion, and it is covered by a metal grid which shields it against mechanical damage.

Production Model

A photograph of the production model * of the Shirley Automatic Size Box as installed on an industrial slasher is shown in Figure 7. The equipment forms a self-contained unit which replaces the ordinary size box. The metering pump is shown driven from the sideshaft of the machine through two P.I.V. (positively infinitely variable) gears working "in series." The speed-ratio control knobs on these gears have pointers moving over graduated scales. One scale is graduated in the percentage of size required on the warp, and the other scale in the weight of unsized warp per 100 yards. Since the stock size has a fixed concentration for all percentages of size, these two knobs, when set to their appropriate graduations, ensure that the correct amount of ingredients is pumped into the box per yard of warp passing through the machine.

A supply of stock size and a supply of water for diluting the size are stored in tanks mounted in front of the size box. These supplies are replenished automatically through level controlling devices of conventional type. The size box itself which is made of stainless steel and has a total capacity of about 11 imperial gallons, is divided into a mixing trough, in which the size and water are mixed together, and a working section, containing the immersion and squeezing rollers and the diaphragm of the dilution controller. This arrangement is shown clearly in the diagrammatic section of the box in Figure 1.

The stock size is drawn from the tank by the metering pump and is delivered to the trough through a narrow slot which is cut along the top of a 2-in. diameter distributor pipe mounted horizontally inside the mixing trough and spanning the full width of the machine. Filtered water is drawn from the storage tank by means of an electrically driven centrifugal pump, which is brought into operation as dictated by the dilution controller and relay. The water is sprayed into the mixing trough across the full width of the machine. The spray is heated by allowing it to fall over a horizontal steam-heated pipe before it encounters the stream of stock size issuing from the slot in the distributor pipe. The inflowing stock size, the water, and the size already in the trough are thoroughly boiled and mixed together by means of open steam from a perforated pipe resting on the bottom of the trough. The mixture flows as required from the trough into the working section of the box through a narrow horizontal slot cut in the bottom of the partition separating the trough from the working section. The size in the working section is kept boiling by means of open steam pipes. The size box is lagged with heat-insulating material, and the bottom of the stock size tank is kept hot by means of a thermostatically controlled water jacket. Since the box is much shallower than a conventional box, two immersion rollers are used; these ensure that both faces of the warp sheet become coated with size before the warp reaches the nip of the squeezing rollers.

Response and Accuracy Tests

A number of experimental trials have been carried out at the Shirley Institute with the automatic size box installed on the slasher. Some of the results of an early investigation are depicted in Figure 8, which shows the times of duration of the operation of the water supply, the concentration of the size in the box, and the percentage of size on the warp, all plotted against the weight of warp which had passed through

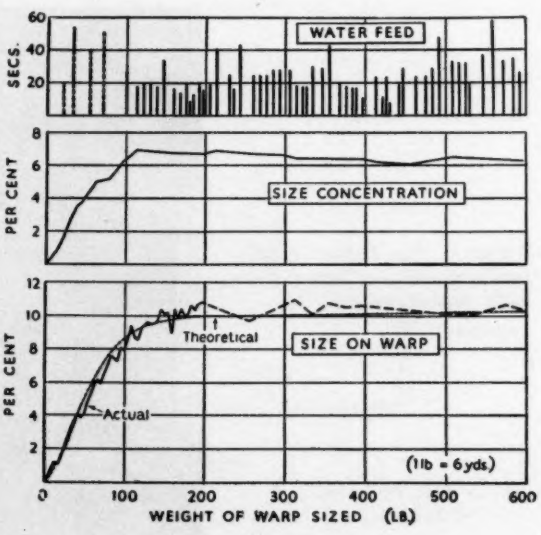

FIG. 8

* Messrs. Joseph Hibbert & Co. Ltd., Darwen, England, have been granted exclusive rights for the manufacture and sale of the Shirley Automatic Size Box.

the machine from the start of the experiment. Since this trial was intended to test the response of the system under extreme starting conditions, the box was initially filled with pure water instead of size. The target percentage of size was 10.2%, and this particular box had a capacity of about 7 imperial gallons. The rate of approach to this percentage, as anticipated from theory, is shown by the smooth curve. The actual approach was not smooth, but followed a jagged line. On the average, this line follows the theoretical line, and is considered to be a very satisfactory confirmation of theory. Once equilibrium was achieved, the actual percentage of size on the warp never varied by more than 0.8% of size from the target percentage.

The rate of approach to equilibrium is interesting because it gives an idea of the weight of warp which must pass through the machine to get to within a certain percentage of size from the target percentage. Starting with water would, of course, be quite absurd in the routine use of the box, and, in practice, the percentage of size put on the warp at the start need be no further from the target than it is when sizing with conventional equipment. For example, suppose that when aiming at 10% of size on the warp, the initial percentage was somewhere between 7% and 13%; then, after sizing about 30 lbs. of warp—say, a third of a beam—the percentage would be somewhere between 9% and 11%. Even during the sizing of this early part of the beam, the average percentage of size would be nearer the target than when sizing with the ordinary type of box.

Some Advantages of the Box

The automatic size box can be used advantageously in every instance where a conventional size box is employed. The user retains complete freedom of choice with regard to the sizing ingredients and the sizing conditions, such as the weight and covering of the squeezing roller and the temperature of the size. Size preparation is greatly simplified because a single concentrated stock size is usually all that is required to cover the whole range of sizing on all the slashers in any one mill.

The greatest advantage of the use of the box is undoubtedly its effect on raising the standard of weavability. In this connection it is important to remember that, although the box will put any specified percentage of size on the warp, good weaving will not result unless this specified percentage is also the best for weaving. A knowledge of the optimum percentages of size for the various types of warp being woven is therefore essential if full advantage is to be taken of the capabilities of this new method of control. Unless this is understood, comparative weaving tests between warps sized on the automatic size box and warps sized by conventional methods can be very misleading.

Industrial experience has shown that where knowledge of the optimum percentages of size for weaving has been available and has been applied in setting the controls on the box, a very significant improvement in weaving has been achieved.

A secondary advantage of the box is that it is likely to reduce the consumption of sizing ingredients. This is because, with the risk of undersizing largely eliminated, there is less necessity to size "on the top side." Consequently, the average percentage of size put on the warps can often be one or two units lower than when sizing with conventional equipment.

Wide Application of Principle

It should be emphasized that the application of the principle of the automatic size box is not limited to warp sizing. The principle can, in fact, be applied to most textile and nontextile processes in which it is necessary to deposit a prescribed percentage of any substance on a moving sheet of material passing through an impregnating bath containing a solution or suspension of the substance.

Cotton and Ideal Military Textiles

S. J. Kennedy*

Office of The Quartermaster General, Washington, D. C.

WHEN my good friend George Buck asked me to participate in the Cotton Research Clinic, I accepted with some hesitation as to whether there was anything about cotton I could possibly tell you. When I read the program, which outlined so much that is being done to apply the results of research and to open up new areas for the improvement of cotton manufacturing and the making of better and lower-cost cotton textiles, I felt even more sure that this was not a meeting at which the special needs of the military would be of a great deal of interest.

However, on further thought, I could not help remembering how the textile industry has distinguished itself in emergency periods, such as during World War II and the war in Korea, by its intense patriotism and its desire to fulfill its share of the national military requirement. Also, the splendid work which the National Cotton Council has done in sponsoring research and the understanding and application of research results within the industry are some of the most impressive accomplishments in the textile research field within the past decade. Accordingly, I am both pleased and honored to be with you today, and to be able to give you some insight into what we in the Army Quartermaster Corps expect from cotton in meeting some of our military needs.

The role of textiles in national defense is more important and more far-reaching than most people realize. Many people regard textiles in much the way that economists regard "free goods"—like the air, something that is always there, and that we don't have to be concerned about very often. We need only to go to this industry with our needs, and almost overnight it turns out specialized military textiles which meet quite exacting specified requirements. Perhaps it is because the industry has done such a remarkably good job that people have come to take its good work somewhat for granted.

The danger of such an attitude and the failure to recognize a special relationship between textiles and military operations are well illustrated in what General Heinz Guderian, Panzer Leader of the German invasion of Russia in 1941, said about the terrible effects of the failure of the German leaders to provide winter clothing to their Army as they lay stalled before Moscow when the record cold of the winter of 1941–42 closed in around them. Hurried-up requests for winter clothing were met with the statement that they should not make unnecessary requests of this type and that the troops would get their winter clothing in due course. When General Guderian pressed his point and flew back to make a personal request of Hitler for warm clothing, saying that twice as many of his soldiers were becoming casualties from the cold as from the fire of the Russians, he was relieved of his command. So hard is it for people who otherwise can conceive of the problems of military operations in broad terms to think of such simple things as clothing and shoes and textiles!

At times it has seemed that it would be interesting to see to just what uses textiles are put by the military services. However, each time that we begin to compile such a list, it gets to look more like a list of all peace-time textile uses—with just shifts in emphasis. A list of that kind would be much too long to attempt to discuss here.

The question we shall consider herein is: "What makes a fiber or a fabric an ideal material for a military use like clothing or tents?

In general, textile fibers derive their utility in military uses from three principal factors: (*1*) their performance characteristics, which adapt them to particular end-use requirements; (*2*) their cost relative to alternate textiles or other materials which can meet the functional requirements; and (*3*) their availability in adequate supply within the country.

Military Textiles and Their Performance Requirements

The performance characteristics are determined by a consideration of the end-item and how it is to be used. From the statement of the required military characteristics, which outline the requirements for the item, can be derived a list of needed characteris-

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tics for the various component parts and materials. These, in turn, must be translated into the mechanical properties of the fabrics, the finishes, or the fibers themselves.

Accordingly, in order to understand the role of cotton or any other fiber in a specific use, like the soldier's clothing system, we must look at that clothing as an integrated whole in terms of the complex functions it is expected to perform.

From this viewpoint, one will observe that the clothing of today's combat soldier, together with certain related gear, provide a coordinated system of protection. This system of protection embraces three areas: protection against the environment, concealment from observation, and protection against enemy munitions. The chart illustrates in schematic form some of the factors involved in each of the three types of protection required by the combat soldier and some of the means utilized to provide such protection.

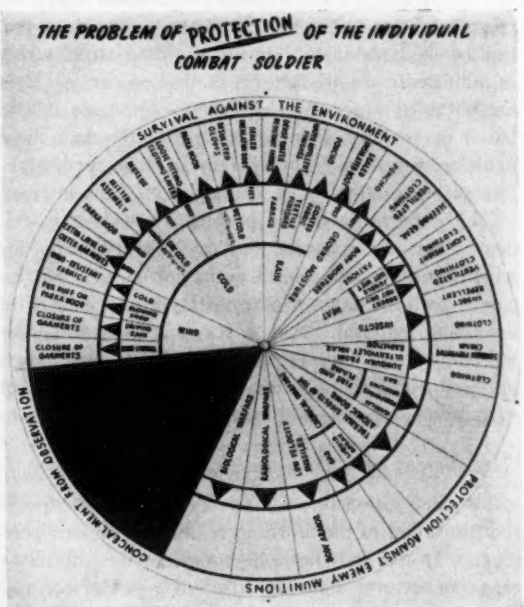
The first of these problem areas embraces a wide range of climatic and terrain factors, which may be regarded as environmental factors confronting the soldier in the field.

It is important to keep in mind that there is an interrelatedness between all of the natural environmental factors and the human factors, such as the physiological and psychological responses and tolerances of man. Actually, the problem is far more complex than that. It is really a multidimensional problem, because there are numerous other factors involved, such as occupation-imposed factors and material-produced factors—those associated with the specific tasks the soldier has to do, such as working a radio set or a skysweeper, etc., as well as the limitations which the particular fabrics or items of clothing place upon the freedom of movement of the wearer.

Furthermore, man is a living being who produces body heat and eliminates moisture through his skin surface, who is subject to a wide range of levels of activity, and who may or may not make the adjustments in his clothing system, which was designed with the idea of these adjustments being made under particular ambient conditions.

These factors are quite important in working with such a problem as selecting materials for a clothing ensemble with which to protect the soldier against the cold.

This problem is almost as old as survival itself, and most of the principles governing the clothing you and I wear were worked out subconsciously in the far-distant past. In fact, we take them very much for granted, so that when we must consider fundamental changes in our fibers or fabrics for clothing systems, we tend to resort to a trial-and-error basis.


THE PROBLEM OF PROTECTION OF THE INDIVIDUAL COMBAT SOLDIER
SURVIVAL AGAINST THE ENVIRONMENT
PROTECTION AGAINST ENEMY MUNITIONS
CONCEALMENT FROM OBSERVATION

Cold-Weather Clothing

Cold-weather clothing of conventional types actually is a system for conserving body heat. Clothing of this type is not warm in itself; it is merely a good insulator and a poor conductor of heat. Since still air is the best insulator known the best cold-weather clothing is that which entraps a considerable amount of air, and in which the insulating medium can be kept dry both locally and throughout the system.

Conventional clothing recognizes really only three concepts from the standpoint of protection: first, a layer of washable fabric which can be worn next to the skin; second, insulating layers of one kind or another; and, third, systems of closure which will reduce convection currents around the upper body.

However, in really cold weather, such as that in Minnesota and in the far north, such clothing is not enough. Where there are high winds combined with cold temperatures, clothing must also be windproof, or the insulating system will not have a chance

to work efficiently. A certain degree of windproofness can be obtained through the use of very thick boardy woolen fabrics, which are also expected to serve as insulating fabrics. This is an inefficient approach, however, since such fabrics serve well for neither purpose.

The development of the British Grenfel cloth about 20 years ago and of the American counterpart, Byrd cloth, opened the way for a vast improvement in cold-climate clothing by adding a wind-resistant layer to the outside of the clothing. The U. S. Army adopted this principle in 1943—namely, shielding the insulating layers of the system from the wind by means of a wind-resistant outer layer of cotton fabric. More recently, both the Canadians and British armies have adopted the same principle.

The present wet-cold climate uniforms of the Army which would normally be worn during a winter in combat areas having the general climate of northern Europe or most of the northern part of the United States, under average daily temperatures of from 14°F up to 68°F, is today comprised of a jacket made from a double layer of wind-resistant, water-repellent cotton fabric, into which is buttoned an insulating layer of wool-cotton frieze cloth in the form of a liner; a further insulating layer of a heavy wool shirting comes next, and finally the underwear. It is quite a simple system, but its performance hinges on the effectiveness of the cotton fabric in preventing the wind from passing through and disturbing the pockets of still air that serve as insulation in the system, and in keeping out water that would raise the conductance levels of the fabrics, as well as drain off body heat through forcing the body to evaporate moisture from the skin surface. Since this outer layer of fabric is the most critical element in the clothing system, and is the major "new" use for cotton in combat clothing, it might be well to consider how well cotton performs in this role.

While we are pleased that the system works reasonably well, it should be frankly stated that it leaves a good deal to be desired. For example, in the jacket a double layer of fabric must be used, since two layers are several times more water-resistant than a single layer.

The fabric for the outer layer is a 9-oz. combed sateen, and that in the second layer or liner is a 5½-oz. combed Oxford. The latter fabric is constructed on principles developed originally by the late Fred T. Peirce, and is one of a group of fabrics developed in connection with a contract of our Office with the Institute of Textile Technology. It has a construction of 196 × 86, and breaking strengths of 180 × 80. The warp yarns are approximately 80's, 2-ply, with single 40's in the filling. Since this fabric receives little wear, we regard the Oxford construction as satisfactory for this purpose. The sateen fabric has a construction of 112 × 68, with breaking strengths of 150 × 125, and is made from 36's, 2-ply and 24's, 2-ply. It has good tear-resistance, good abrasion-resistance, and reasonably good wind- and water-resistance.

The jacket made from these fabrics weighs 3.36 lbs. in medium size. Frankly, that is too heavy. When added to the other clothing the soldier must wear and the rest of his gear, ammunition and rifle, we are penalizing him by making him carry a heavy garment, which weighs even more when it gets wet.

What are the prospects for simplifying these fabrics and holding down over-all weight? Three possible approaches, so far as the cloth is concerned, are as follows: through greater evenness of yarns, through improvements in the mechanical properties of cotton, and through increased tightness in weave of the finished cloth. Studies on yarn evenness and reduction of neps should ultimately lead to improved fabrics and perhaps tight lightweight wind-resistant fabrics made from singles yarns.

The development of improved water-repellent-treated fabrics is another problem. The most that can be said about the status of this matter, which is admittedly unsatisfactory, is that so far we have not obtained water-repellent vapor-permeable fabrics based upon other fibers which are better than those made from cotton. Should they be developed, other factors being equal, they would be of great interest.

The importance of the problem of weight is evident when we consider the dry-cold clothing, for which the man puts on an extra garment. This includes both an outer windproof layer and a layer of insulating material. Any extra weight beyond what we really must have is paid for here at a very high premium, and the lightest-weight fabrics consistent with other properties are much to be desired.

Concealment from Observation

The first aspect one thinks of in this connection is the coloration of the fabric in relation to the environment. However, when one considers the enormous range of natural color in different types of terrain,

different types of vegetation, and during different seasons of the year, one would have to have the capacity to change color like a chameleon if his clothing were to blend with the environment at all times. This is one area where compromise is essential, and colors must be chosen which will do the most for the soldier under the particular conditions and at the particular ranges at which individual camouflage is considered to be most important.

However, color by itself is not the only thing important to camouflage. Texture also is very important, but it is one thing which is very difficult to incorporate into an outer layer of material which must simultaneously be windproof and water-repellent. Elimination of gloss also is desirable. However, this is difficult to achieve in a product which the industry insists on mercerizing as a part of the process of dyeing. We hope before too long to be able to eliminate or prohibit mercerizing in the interests of reducing gloss on the fabric.

Then, of course, there is the problem of detection of the soldier through photographic and infrared detecting devices, which raises a wide range of problems of its own.

Combat Protection

I am simply going to enumerate some of the ways the individual soldier may be protected against enemy munitions without attempting to go into some of the ways in which clothing may contribute to the protection of the soldier. They include protection from biological agents, radiological agents, low-velocity missiles, gas and liquid spray, and such fire and flame agents as napalm and phosphorus.

After all, if the clothing is what is interposed between the man and these various types of weapons, it must be expected to play a role in protecting him, either by intent or by indirection.

Take the case of body armor, which has been proven to be especially useful in Korea in the actual saving of many lives.

An ideal textile for this purpose would certainly be one of high strength. Nylon is the textile fiber used today for the making of armored clothing such as the Quartermaster Corps is presently supplying. It is the best fiber available for the purpose. That does not mean that other fibers, such as cotton, might not be useful in stopping missiles. In fact, ordinary clothing has a certain value, but it is not enough to be significant. However, for cotton to do the job, there would have to be so much of it around the man that he would be immobilized. With nylon we can reduce casualties significantly be the use of a vest weighing only 8 lbs., which is within the range of what a man may be able to carry in addition to his other loads under a fairly wide range of combat conditions.

For protection against certain chemical agents, during the last war we used impregnated clothing. Obviously, garments made for this purpose must be constructed from fibers which are capable of taking such treatments.

There is another class of munitions which has become very important and which places a particular stress upon combat clothing—that is, the flame or thermal type of weapon. Napalm or jellied gasoline was widely used by our forces in the Korean war. It proved to be an effective weapon, as the napalm bomb neutralizes a relatively large area on the order of 30×80 yards with a fireball in which very high temperatures are registered at ground level for upwards of several seconds. Both temperatures and active flame are present at such levels that clothing catches fire and adds to the heat stress of the individual the further heat from active flaming of his clothing as well as the resultant loss of its insulating value. Added to this physiological hazard is the very considerable psychological effectiveness of flame as an offensive weapon.

While there is a great deal more that could be said on this subject, it may be noted that the problem is quite complex where so much energy at levels above the burning point of clothing is released in such a short period of time. It is apparent that combat clothing should be flameproofed in one way or another, preferably by treatments which will withstand repeated launderings and which will be free from afterglow.

When this requirement is added to the others that have been listed for the outer fabric of this clothing system, the available fibers that will be satisfactory are quite sharply limited. Cotton is still the best fiber for this purpose, assuming that a satisfactory flameproof treatment can be developed, as presently is expected, which will not adversely affect other properties.

Hot-Climate Clothing

The physiological situation for hot-weather clothing is the reverse of that for a cold-wet climate.

Here we require a clothing system which, instead of being designed to conserve body heat, is geared to help the body achieve a high level of efficiency in its normal cooling process. This process is most effective when, other conditions permitting, the body is devoid of clothing. Normal combat conditions require environmental protection of a different kind than in the cold, but they do necessitate a form of protective clothing against many terrain factors.

For example, in the Savannah areas there is the "kunai" grass with its broad sharp-edged blades, which grows to a height of from 4 to 7 ft. In the rain forests, where walking is difficult and dangerous, one may suddenly sink up to the thighs in vegetation and stagnant pools. There are steep chasms where one may slip and slide. Furthermore, there are many plants which contain poisonous or irritating substances in their leaves, thorns, bark, sap, roots, seeds, or fruits. There are harrassing fauna, especially leeches, which crawl out on the leaves of trees and attach themselves to the skin. Fresh-water streams contain parasitic liver and intestinal flukes, and numerous kinds of mosquitoes carry malaria, dengue and yellow fever, and filariasis.

Actually, there are two separate types of conditions one thinks of in connection with clothing for the tropics: the hot-wet or jungle environment, and the hot-dry or desert environment. These two areas are defined in terms of climatic extremes, but the conclusions with respect to clothing suitable for them are applicable also to less severe hot climates.

For the jungle it has been quite conclusively demonstrated that a fabric as thin and lightweight as possible, tightly woven, with a high degree of water vapor permeability and highly absorbent, is to be preferred. Where mosquitoes and other insect vectors of disease and sharp thorns that may snag and tear the clothing are not a problem, the fabric may be opened up and made porous. However, a porous thin fabric may be objectionally sleazy, if appearance is to be counted a factor. Rapid transfer of body moisture to the outer surface by absorption or vapor transmission is essential to comfort, since in high-humidity environment water evaporative cooling must be encouraged by every practical means.

For this type of clothing, cotton is quite acceptable. However, cotton does not make strong lightweight thin fabrics, except at great cost, and under ceilings of strength that are objectionably low. A cotton with the tear strength of nylon would make wonderful jungle or hot-wet clothing.

The other type of climate is the desert or hot-dry. Here the problem is not so much one of encouraging evaporative cooling, but rather of getting enough water to the man to keep his body-cooling system working. Generally speaking, the principal difference is that in this case thicker fabrics which provide a measure of insulation and protection against solar radiation are desirable. Looseness of clothing is also very important. For combat wear a tight weave may be desirable, whereas for noncombat wear a porous weave may do very well.

Cotton does a good job in this case also, especially since in combat clothing launderability is stressed as the most practical field measure for keeping the soldier's clothing clean. Where appearance is a dominating factor, as with summer uniforms, other fibers may have an advantage, particularly where dry-cleaning facilities can be made available.

Tentage

While field requirements for tentage fabrics have certain similarities to those of clothing, there are important differences.

Tents may be divided into two categories: lightweight man-portable tents, for which light, strong, combed cotton fabrics are presently being used; and the larger vehicle-portable tents, for which cotton plied-yarn duck and single-yarn sateens are used. The place of these lightweight portable tents has gradually been increased from a military standpoint at the expense of larger heavier tentage made from cotton duck.

Fire-resistance is a most important requirement for all components of both types of tents—for duck fabric, sidewalls, webbing, liners, and even rope. Water-resistance is also important, also with somewhat different parameters than in clothing, where contact and flexing reduce whatever water-resistance can be imparted to the fabric. In the lightweight tent fabrics, we rely on conventional water-repellents and low add-on types of fire-retardants to give a finish which will be flexible even at very cold temperatures and which will not add excessively to the weight of the tent. In the heavier vehicle-portable types of tentage, we are still using the fire-, water-, weather-, mildewproof resin finish based on the use of antimony oxide and chlorinated paraffin, but we are actively engaged in trying to reduce the add-on and also improve cold-temperature flexibility.

For both types of fabric, but especially in the heavier weight tents, resistance to solar radiation is

a highly important factor. The finish which we have been using gives a very impressive performance in this respect. Fabrics treated with it have withstood outdoor exposure for upwards of 5 years, with clear indications that the finish has successfully contributed resistance to solar radiation.

Now as to the question: How does cotton meet these requirements in our present fabrics?

Lightweight tents made of cotton are considerably overweight. In order to get the desirable strength, particularly tear strength, we have had to use weights of fabrics which are excessive in the light of the requirement. Fire-resistant treatments pull down tear strength significantly. The problem of high tear strength fabrics for these tents is critical, especially for the 2-man tent and the 10-man tent.

In the heavier weight tents, plied yarns are an unsatisfactory material, because of the inescapable shortage of capacity in time of war. Single-yarn sateens have been developed, the performance of which appears to be better than that of the plied-yarn ducks when actually used in medium-size tents. Also, we have developed fabrics using cotton warps and high-tenacity rayon fillings which are most impressive in performance and which would give relief to plied cotton yarn capacity in time of war.

The fire-resistant requirement as a major factor in tentage gives cotton fabrics a preferred position, because of their ability to receive such treatments for protection against flame at low cost.

Cost and Availability Factors

Regarding the matter of cost, it is important to note that the historical position of cotton as the lowest cost general-use textile fiber has recently been lost to regenerated cellulose staple fibers. Whether this reversal of position is permanent or not, the fact is important to note, because it may affect numerous uses which cotton has held in the past by virtue of its price position.

That the properties of these other fabrics at present makes them less satisfactory than cotton for many uses should not be counted upon too heavily. The attitude in cotton-importing countries of starting to use these fibers in blends with cotton or in place of cotton because of their more favorable price position is considered rather significant. The research being directed abroad towards developing these blends into satisfactory military fabrics may lead ultimately to a more favorable attitude toward some of these blends on the basis of international standardization. Technical developments have a way of following in the wake of such basic economic situations as well as preceding them. Accordingly, this line of development in countries abroad is certain to continue, and will be of interest to many people in this country.

Much does not need to be said about the availability of cotton; it seems almost to be too available, in this the world's largest cotton-producing country. Except in those years when the crop is abnormally small, or where the carry-over is at a low level, it is pretty much taken for granted that there will be an adequate supply of cotton to meet all foreseeable military requirements. In this respect cotton is an ideal military fiber for the Armed Services of the United States, and as technical progress continues among growers and manufacturers, it will undoubtedly continue to find many uses where its properties make it the preferred textile material for a long time to come.

Tar Spot Removal from Cotton Fabrics During Finishing

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TAR AND ASPHALT contamination of finished cotton fabrics has plagued the cotton industry for many years [1, 3]. For the majority of the cotton manufacturers this has presented no great problem in the past, since the presence of these materials in small amounts in industrial and dark-colored fabrics did not adversely affect sales, and thus the efforts of the minority—for which contamination was a problem—were largely ineffective in bringing about corrective measures. With the introduction of new finishes for cotton apparel, drapery, and upholstery fabrics in recent years, however, such as embossing, polishing, glazing, and schreinering, the problem is now more widely recognized as being quite serious [1]. When minute tar or asphalt particles that would escape detection in most cotton fabrics are subjected to the hot calendering operations in these finishing processes, they appear either as large black spots or long black streaks in the finished goods, which may cause the fabrics to be classified as seconds [2]. The sale of plain apparel fabrics in white and pastel shades has also been affected by tar and asphalt contamination, particularly since rayon and synthetic fibers are not bothered with this contaminant and cotton must compete with these on the open market. It is quite evident that in order for the cotton industry to place competitive high-quality apparel fabrics on the market, tar and asphalt must be eliminated from the finished goods.

Two approaches to the elimination of tar spots from cotton goods have been made by the Institute: (*1*) to determine the source, or sources, of tar and asphalt contamination, and, having done this, to remove the source or sources; and (*2*) to perfect methods for the economical removal of tar and asphalt from cotton fabric. The present researches are concerned with the latter approach, and include the development of formulations and procedures for removal of tar and asphalt contaminants: (*a*) during finishing, as well as (*b*) after finishing, as a salvage operation. After 4 years the objective sought has been gained in large measure.

Researches directed toward the elimination of contaminating sources have not as yet been very successful. It is felt that a cooperative effort among the various segments of the cotton industry, from the farmer to the finisher, will ultimately lead to cotton harvesting and packaging procedures that should eliminate contamination at the source. Several years will undoubtedly be required to effect the necessary harvesting and packaging legislation after successful procedures are developed. In the meanwhile, economical remedial procedures are being offered to the cotton textile industry by the Institute.

Sources of Tar and Asphalt in Cotton

The work [3] of the National Cotton Council indicates that 90% of the tar and asphalt particles responsible for tar spots in finished goods are located

FIG. 1. *Tar particles attached to* (A) *and spun into* (B) *cotton yarn.*

* Technical Director.
† Research Assistant.

on the outside of the cotton bale as received at the cotton mill and less than 10% are inside the bale. This conclusion indicates that the bales become contaminated primarily during transportation and storage. Some of the possible sources of contamination include: cotton fields bordering on freshly tarred roads (thrown by car or truck wheels); tar-treated picker sacks; dropped from airplane wheels while dusting crop; from wagon wheels while hauling cotton to gins; thrown by tractor wheels at gins; loading platforms at gins, warehouses, or mills; melted roofs at gins, warehouses, or mills; reused bagging and bale ties; thrown up by truck or trailer wheels in hauling; insides of railroad cars; starter switches in fluorescent lights; belt dressings or hard greases.

Appearance of Cotton Yarns and Fabrics Contaminated with Tar and Asphalt

Cotton Yarns

The mode of attachment of the tar spot to the yarns varies (Figure 1). In certain cases the asphalt adheres to the surface of the yarn as though it had been stuck there (Figure 1A), whereas in others the particle seems to be spun into the center of the yarn (Figure 1B). When the tar particles, or tar slubs, are sufficiently large, they may be responsible for increased ends down during spinning.

Cotton Fabric

The appearance of a tar spot woven into an Oxford fabric is shown in Figure 2. The same fabric after unravelling reveals the tar spot to be present as a tarry slub which was present when the yarn was being spun (Figure 3).

In a fabric of different construction (Figure 4), a similar situation exists. The photographs shown in A and B of Figure 4 were taken on opposite sides of the cloth and show that the tarry slub is in the yarn. In Figure 4C the tar is being lifted by a needle.

Embossed and Calendered Cotton Fabrics

Small tar particles in finished cotton goods, which ordinarily would escape detection, become quite large when subjected to heat and pressure, such as is used in embossing and glazing cotton fabrics. In the upper half of Figure 5 is shown a tar spot in an embossed cotton fabric. This fabric was dyed a light yellow. By the use of a spotting technique, the tar spot was eliminated, as may be seen in the encircled area in the lower half of Figure 5. The two residual black dots in the circle are pin holes in the fabric and not tar. In place of a black spot, there was left a white spot, since the tar prevented the dye from penetrating into the fabric. In the finished goods,

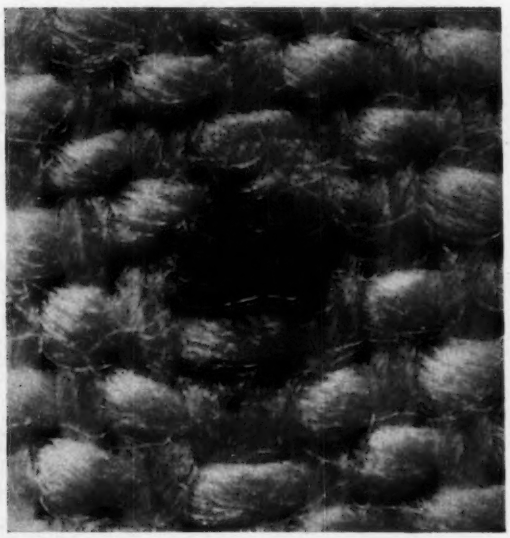

FIG. 2. *Tar spot appearance in Oxford fabric.*

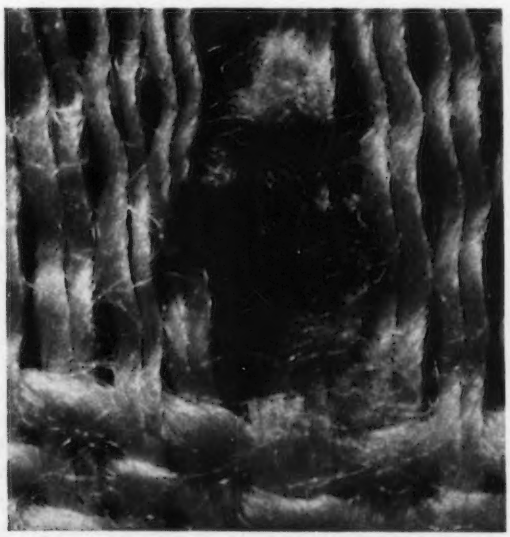

FIG. 3. *Unravelled Oxford fabric revealing tarry slub in yarn.*

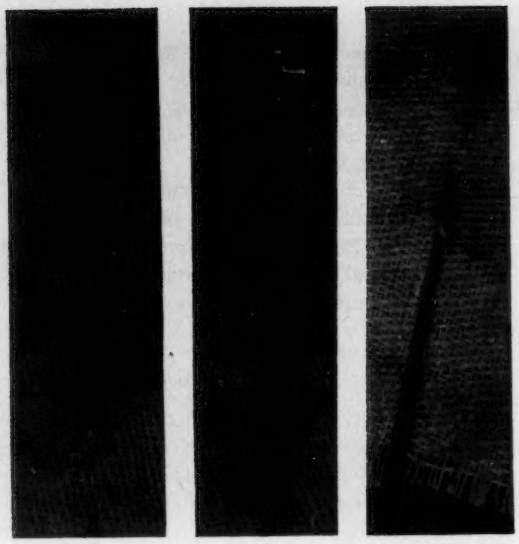

FIG. 4. *Tarry slub in yarn woven into a different fabric construction.* A *and* B*—Taken on opposite sides of fabric.* C*—Tarry slub being lifted by needle point.*

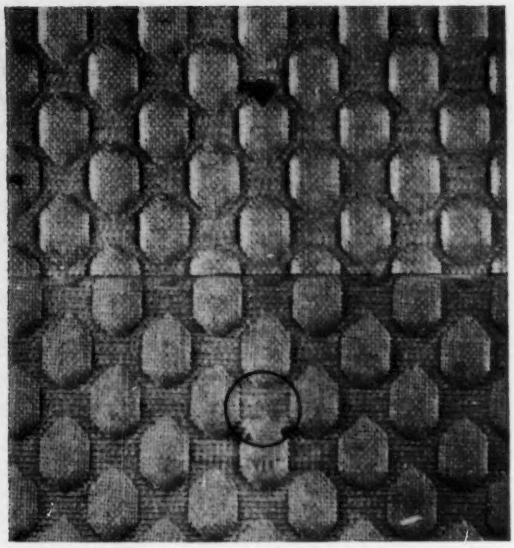

FIG. 5. Upper—*A tar spot in yellow embossed cotton fabric.* Lower—*Tar spot removed by spotting technique, leaving white spot.*

the white spot may be as objectionable as the black tar spot. The occurrence of the white spot proves, however, that the tar spot was on the fabric before it was dyed.

In the case of glazed fabrics, the tar spot may often become a tar streak. In these cases, the use of a dry solvent spotting technique is about the only way to prevent the goods from being classified as seconds.

Removal of Tar Spots from Cotton Goods after Finishing

Tar spots in finished cotton goods may be removed after finishing by the use of spotting techniques, and during finishing operations by the use of special additives and processes. The former procedure is the more expensive, but often must be resorted to in order to prevent excessive fabric grading losses.

Spotting Techniques

The various spotting techniques applicable in this work are: (*a*) steam spotting—application of a tar solvent, followed by steaming; (*b*) water spotting—application of a tar solvent followed by water (fabric placed over an absorbent pad during the application); (*c*) Dry solvent spotting—application of a tar solvent followed by application of a second miscible organic solvent to the fabric placed over an absorbent pad.

Conventional steam spotting units are of three types *—namely: (*I*) single steam separator and gun; (*II*) double steam and water separator and gun; and (*III*) triple steam separator with steam, water, and compressed air chambers and gun.

Type *I* steam spotting units usually deliver wet steam, which is suitable for this work, except on extremely hot days or after extended use, when the steam becomes practically dry and is then less effective.

Type *II* steam spotting units have a double elevation pedal control which when pushed down about half way operate valves which give semidry steam, and when pushed down all the way give a mixture of steam and water. The relative volumes of water and steam delivered can be regulated by means of needle valves.

Type *III* steam spotting units are the same as type *II*, with the exception that there is an additional chamber, valve, and control pedal for compressed air. This unit makes it possible to completely remove all

* Names of manufacturers of steam spotting equipment will be furnished upon request.

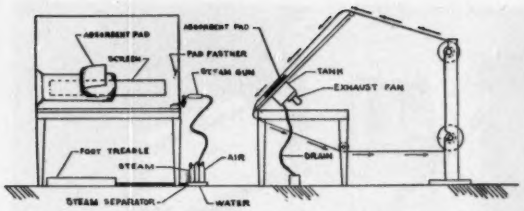

FIG. 6. *Cloth inspection table for removal of tar, oil, and grease spots.*

residual solvents from lightweight fabrics following spot removal. This is quite desirable in most cases.

The applicator gun of these units can be obtained with or without a brush attachment. An attachment for the gun for applying liquid to the fabric by means of a hose from a pressure supply tank is also available.

A convenient spotting device consists of a metal receiver built into a conventional inspection table (Figure 6). The metal receiver, or box, is 36 in. long, 10 in. wide, and 6 in. deep, and has a 40-mesh stainless-steel screen cover which can be removed for cleaning. The box should be equipped with a vacuum fan and liquid drain, as shown in Figure 6. The length of the metal receiver should be slightly less than the width of the cloth being inspected.

A tar solvent formulation found very effective in spotting tar-contaminated cotton fabric consists of: 4 parts Monopole oil, 1 part isopropyl alcohol, 95 parts tetrachloroethane by volume.

A solution of 1 part Monopole oil and 9 parts of tetrachloroethane by volume has also been found satisfactory in certain cases. On cellulose acetate or cotton cellulose acetate blend fabrics, xylene should be used in place of tetrachloroethane in these formulations.

A number of commercial tar spot removers * are on the market which are suitable for use in the steam and water spotting methods.

The salvage of tar-contaminated cloth by use of spotting techniques is much more expensive than the treatment of greige fabric by the kier or quench-box methods. Unfortunately, it is impossible to readily differentiate tar particles in greige fabric from leaf and seed-hull fragments. Attempts made to remove all black particles during inspection increases the cost of the spotting method to a point where it is uneconomical.

* The names of tar spotting agent manufacturers or jobbers will be furnished upon request.

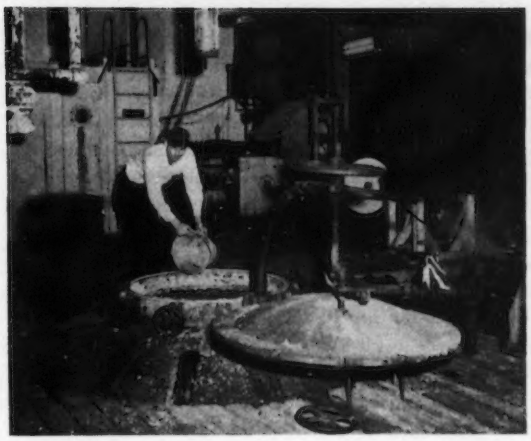

FIG. 7. *Addition of a sulfonated oil-xylene (9:25) mixture to the pressure kier containing 1% caustic and cotton fabric. (Photograph by courtesy of Rock Hill Finishing Co., Rock Hill, S.C.)*

Care must be exercised to use spotting chemicals which are readily removed prior to dyeing and/or resin treating; otherwise, light or dark spots may show after dyeing, or soft areas may be found in the resin-treated fabric.

Soap Emulsions in Organic Solvents

The removal of tar spots in bleached fabric may also be accomplished by the application of a soap emulsion containing a large proportion of organic solvents. The emulsion is padded on the entire fabric, given a rest period, and washed in a slack rope washer with soap and hot water. This procedure is effective; however, it is expensive, costing about 1.5 cents per yard.

Removal of Tar Spots from Cotton Goods During Finishing

Pressure Kier Procedure

As a preliminary to this approach to the problem, a small pressure kier was built, and many formulations were tested in the laboratory. It was found that the addition of about a 7% sulfonated oil (75%)-xylene (9:25) mixture, on the weight of the goods, to a 1% caustic charge in the kier was quite effective for the removal of tar spots. In translating this into commercial operation, it was found that the best procedure was to first charge the kier with 4 tons of cloth, and after the addition of the caustic a mixture

of 18 gals. of sulfonated oil and 50 gals. of xylene (xylol) was poured on top of the charged load in the kier (Figure 7). Circulation of the liquor was then started, the kier was closed, and the pressure was raised in the customary manner. The relief valve in the lid of the kier should be closed as much as possible to prevent loss of the xylene, yet open enough to allow the excess air to escape. After completion of the pressure boil, a light wash-down with warm water is given. If the fabric is then washed in cool or cold water, and bleached, it will be found that about 85% of the tar spots have been removed. However, if a hot wash (140°F to 160°F) is given, close to 95% removal efficiency will have been realized.

Due to the use of an organic solvent, xylene, in the kier process, it is essential that the kier pump and lines be thoroughly cleaned before starting the run. If the circulating pump is packed with the conventional graphite packing, this packing should be replaced with a caustic- and solvent-resistant packing. If this is not done, finely divided graphite in the pumping system may be loosened and uniformly deposited on the cloth in the kier. In one cooperating finishing plant, greying was a problem, even though the kier had been thoroughly cleaned and the packing changed. In this plant a peroxide bleach was given in the kier after the caustic run. Upon washing, the fabric was found to be grey. The difficulty was eliminated by passing the peroxide-bleached fabric through acid and subsequently giving a light bleach with hypochlorite.

The sulfonated oil-xylol pressure kier method has proven to be quite effective and economical, since the chemicals cost is less than 2 mills per yard on 4-oz. cloth.

Another formulation which has been found to be equally effective in the pressure kier consists of about 7% pine oil-sulfonated oil (75%) (1:1)-xylene (9:25) mixture, on the weight of the goods. The chemical cost of this formulation is about 1.5 mills per yard on 4-oz. cloth.

Quench-Box Procedure

Due to the trend in the finishing industry to change from the use of pressure kiers to continuous bleaching, it was realized that a continuous process for tar spot removal would be needed by many finishers.

After many months of research and commercial trials, it has been found that by the use of a mixture of pine oil and kerosene in the quench box, containing caustic under the proper conditions, at least 95% of the tar spots can be removed from cotton print cloth and other goods of about the same weight.

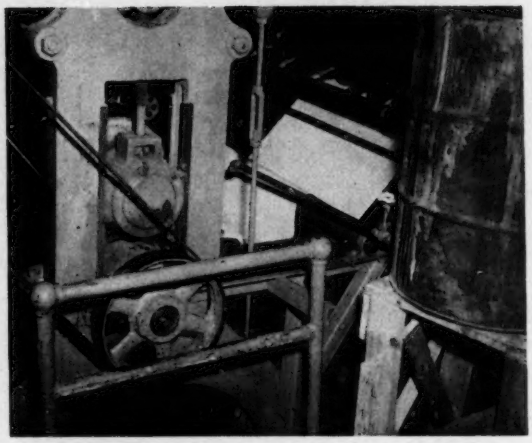

FIG. 8. *Continuous addition of a pine oil-kerosene (1:9) mixture to the quench box containing 0.5% caustic heated to 150°–160°F while fabric is passing through at the rate of 150–200 yds./min. (Photograph by courtesy of North Carolina Finishing Co., Salisbury, N.C.)*

In the large-scale tests an open-end, 55-gal. drum was fitted with a valve and pipe line so that the pine oil-kerosene mixture could be continuously added to a highly agitated point in the quench box, while the fabric was passing through at the rate of 150 to 200 yds./min. Once the process is adopted by a finishing plant, permanently mounted tanks and metering pumps may be installed.

The quench box was filled to a normal running level with 0.5% caustic heated to a temperature of from 150°F to 160°F. No soap or other surface-active agent should be added to the caustic. A layer of a mixture of 1 part pine oil and 9 parts kerosene, about ½ in. thick, was then run onto the surface of the hot quench liquor. The singer was started, and the pine oil-kerosene mixture was metered into the quench liquor by use of a valve at a rate of approximately 7 gals. per 1,000 lbs. of fabric (Figure 8). On 80 × 80 print cloth this is equivalent to about 1.7 gals. per 1,000 yds. The caustic level is maintained in the customary manner.

A normal nip roll pressure is used. This results in a pickup of between 60% and 70% of the treating liquor.

The treated fabric is then run into a greige bin and given a 4-hr. rest period. Subsequently, a continuous hot-water (160°–180°F) wash is given the fabric.

The conventional finishing procedures are followed after the above treatment. The fabric can either go through acid and be kiered, or be put through a continuous boil-off and bleaching range.

Although commercial tests have not been made as final proof, the laboratory findings indicate that if a soap wash could be given following the rest period instead of a hot-water wash, 100% removal of tar spots could be accomplished.

As an example of the efficiency of the process, cotton fabric similar to that containing an average of 30 spots per 100 yds., as determined by processing 2,000 yds. of goods by the conventional process, was found to contain an average of 1.5 tar spots per 100 yds. after treatment by the pine oil-kerosene-caustic method followed by a hot-water wash. The spots which were identifiable as having been tar spots were so greatly reduced in solid content that no spotting or streaking was encountered in applying a resin-schreiner finish.

The chemicals cost, including the caustic, was calculated to be 0.427 mills per yard for 80 × 80 cotton print cloth.

Factors Affecting the Economics of the Pressure Kier and Quench-Box Procedures

In the preliminary work in the laboratory it was found that when both the kier and quench-box procedures included hot-water washes, they were quite effective in the removal of warp sizing, as well as tar and asphalt, from the fabrics. For example, it was found that the finished fabrics from the quench-box runs had been as efficiently desized as the control fabric, which had been treated with an enzyme desize. Enzyme desizing costs about 0.307 mills per yard; therefore, if this process can be eliminated, the cost of removal of tar spots by the quench-box procedure will only be about 0.1 mill yer yard for 80 × 80 print cloth.

The full possibilities inherent in the use of the process to accomplish tar spot removal and desizing have not been explored. It is well known, however, that size formulas vary greatly in the industry. Only extended tests under commercial conditions will establish the desizing efficiency of the process.

The laboratory findings also indicate that the amount of pine oil-kerosene mixture used in the quench-box procedure can be decreased by about one third, and still be effective in the removal of tar spots. If this is found to be true in commercial practice, and the desizing effect is still retained, the removal of tar spots can be accomplished at no additional processing cost for any finishing plant which is equipped to give a hot wash after the greige-bin rest period. Finishers may thus find it practical to use this process on all cotton goods, and thereby eliminate possible losses due to occasional tar and asphalt contamination.

Acknowledgment

The authors wish to express appreciation to the several finishing plants that have so graciously cooperated in the commercial testing of the various tar spot removal formulations and processes developed by the Institute. These include: Rock Hill Printing and Finishing Company; North Carolina Finishing Company; Fulton Bag and Cotton Mills; Sayles-Biltmore Bleachery; Arnold Print Works; and the Crompton-Shenandoah Company. The valuable assistance of Mr. T. C. Drew, of Spartan Mills, who served as Advisor from the Institute Technical Advisory Committee during the prosecution of these researches, is also gratefully acknowledged.

Literature Cited

1. Anon., Tar Spots Are with Us, *Textile Inds.* **115**, 110A–110D (1951).
2. Compton, J., and Hubbard, L., "Tar Spots and Quality Control," Proceedings of the Spring Meeting of the Textile Quality Control Association, Apr. 3–4, 1952.
3. Mangum, G. D., Jr., and Buck, G. S., Jr., Exterior Tar Spots Concentration 10 Times That Inside Bale, *Textile Inds.* **116**, 132 (1952).

Symposium on the Cotton Industry Abroad

Four of the papers at the symposium were presented by members of the Cotton Technical Mission which visited Europe in 1953. Sponsors of this series of meetings abroad were the National Cotton Council, The American Cotton Manufacturers' Institute, and the U. S. Department of Agriculture.

The summarized papers which follow contain observations on the cotton textile industry in Europe and a summary of manufacturing practices in the Orient by Dr. Earl Berkley, who visited India and Japan in 1953.

Some Observations on European Cotton Research

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Textile Research Institute, Princeton, New Jersey

MR. George Buck has asked me to summarize the subject of European cotton research in not more than about fifteen minutes. Of course, it is not possible to discuss European cotton research adequately in a brief quarter of an hour. Certainly the total combined research efforts in this field in western Europe are at least equal both in quantity and quality to that taking place in the United States. It will be possible, therefore, only to touch upon the most important subjects: research on fiber properties and laboratory test methods. Presumably, the following speakers will take up matters connected with mill testing and operation.

Without doubt the most comprehensive cotton research program abroad is that of the British Cotton Industries Research Association, commonly known as the Shirley Institute. Here, apart from the chemical research, work on cotton follows three main lines: the investigation of fiber properties, the development of quality control tests, and the study of processing steps. In all three the work is very good. In the fiber laboratory there seems to be considerable emphasis on the characterization of cottons by the routine measurement of fiber fineness by direct weighing methods, fiber maturity by observation of cell wall thickness, fiber strength, by the flat bundle test, and surface characteristics by examination of convolutions, etc. While their methods may not be as streamlined as some of ours, they appear in some instances to obtain properties which have a more direct physical significance than those measured over here. It seems quite possible that their methods may be necessary when one is dealing with many types of cotton from many parts of the world. Under these circumstances some of our shortcut procedures may not be applicable.

At this point it is proper to mention the very thorough and fundamental study of the relation between cotton fiber properties and yarn behavior made by Dr. J. Gregory which was published in a series of five papers in the *Journal of the Textile Institute* [3]. Unfortunately, Dr. Gregory died rather suddenly about a year ago just as he was about to enter the most significant and productive phase of his work. His loss has retarded progress in a most significant field of textile science.

In the development of quality control methods at Shirley, instruments for the evaluation of yarn friction, yarn stiffness, and yarn strength irregularities were of particular interest. So was the small-scale spinning apparatus whereby typical quality yarns can be made with 75 g. or $\frac{1}{6}$ lb. of cotton. These and other instruments are now being marketed through the Shirley Development Company and will soon be available to us over here.

In connection with processing developments at

Shirley mention should be made of the automatic size pick-up control and the electrical resistance drying monitor for the slasher and of the Shirley opener which was described at this meeting last year. These products of Shirley are on a par with technical developments in this country and speak well for the practical application of ideas emanating from the Shirley spinning laboratories. Much of this work is basic rather than superficial as exemplified by the very fine study of the relation between roller slip in the draw frame and the evenness of cotton sliver recently published by Dakin, Foster, and Locke [2] of the Shirley laboratories.

At this point in the discussion it seems appropriate to make a few general remarks about the contributions of university research. It is of interest to observe that with an industry and government-supported organization of Shirley's size carrying out investigations on cotton, there is still room for a great deal of good fundamental research on cotton just a few miles away at the College of Technology in Manchester. Here Professors William Morton and John Preston and Doctors J. W. R. Hearle and Reginald Meredith (a former Shirley staff member) are able to give thought to the problems of fiber behavior without concern for the pressing problems of the industry.

Time does not permit a detailed description of the works by Preston in chemical properties, by Meredith in mechanical behavior and structure, and by Hearle in the field of electrostatics.

However, mention should be made of some recent observations by Professor William Morton [4] whose lifetime has been devoted to studying the cotton fiber. Some years ago, Professor Morton and coworkers adapted a dyed-fiber technique for tracing fibers in assemblies such as sliver, roving, and yarn. This method they have painstakingly applied to the investigation of fiber disposition in such assemblies. They showed that many fibers leaving the card were hooked in the trailing end, and that these hooks were not appreciably reduced in drawing operations. They have more recently demonstrated that the efficiency of comber operation depends greatly upon whether the fibers are introduced into the comber with their hooked ends leading or trailing. Here is a fundamental study which has dividends measurable in dollars and cents as well as in pounds and shillings.

What has been said about the quality of work at the Manchester College of Technology on cotton can also be said about the work at the University of Leeds on wool. And what has been said about the Shirley Institute may also be stated about the British Rayon Research Association, the Wool Industries Research Association, and the Nylon Spinners' Research Association. Each of these organizations is making some worthwhile contribution to fundamental fiber science in addition to its work on practical problems. And in doing so, each is making a contribution to cotton research, for there are many problems in textiles which are common to all fibers.

Two lines of work in English industrial laboratories relating to cotton research are worth mentioning. One of these is the study of balloon tension developed in ring spinning, being carried on by Bracewell and Greenhalgh [1] of the research department of Tweedales and Smalley, textile machinery manufacturers. The other is an investigation of the operation of cards and the mechanical properties of slivers which is being done by Waggett [5] of the Courtaulds laboratory in Coventry.

At this point we might hop over to the European continent to discuss cotton work in two laboratories there, namely, the laboratory of Professor De Muelemeester at the University of Ghent in Belgium and the laboratories of the Vezelinstituut, T.N.O., at Delft and Enschede in Holland. These groups are both working on two cotton problems: warp sizing and the correlation of fiber-yarn properties. In the latter case they are employing the correlation methods of Webb and Richardson in order to predict the yarn properties for the various cottons available to their textile manufacturing organizations. This type of work is fairly familiar to us over here so we might better devote our time to the more interesting story on warp sizing.

In both of these countries the quality of the yarn and the weaving set-ups are such that weaving efficiencies are considerably below ours (some estimates were as low as 70%). There is, thus, room for a real improvement in weaving efficiency by the use of proper sizing procedures. Professor De Muelemeester and coworkers have investigated the influence of size composition, concentration, temperature, squeeze roll pressures, etc., on size penetration into the yarns, yarn strength, fatigue resistance, and on yarn fraying tendencies in simulated looms. At the Vezelinstituut Dr. Van Lingen has gone even further. He has demonstrated that the addition of as little as ½% size increases the dynamic stress necessary to break the yarn by a factor of 2 or 3. Yet, as many of you know, this quantity of size is insufficient to improve appreciably the behavior of the

yarn in the loom. At the same time, Dr. Van Lingen has shown a relation between the frequency of very weak places in the yarn and weaving efficiency. This type of defect, and also the fraying of the yarn in the loom, are, he believes, the major causes of warp stoppages. This illustration shows that cotton textile problems in Europe are essentially no different from ours in the United States.

In Zurich, Switzerland, is located the laboratory of Professor E. Honegger at the Swiss Federal Institute for Technology. Professor Honegger seems to have achieved a nice balance between fundamental research and practical testing. He has a well-equipped laboratory for testing and instruction. He has also contributed extensively to the basic fiber field and to problems of quality control testing. Examples of this are his applications of scientific principles to the Uster automatic single-end yarn tester and to the Uster "stapling instrument" for giving number-length distributions of cotton fibers. Both of these instruments were developed in this laboratory.

It is of interest to note that Zellweger, A. G., the company which makes the "Uster" line of testing instruments, is a textile machinery manufacturer. Most recent addition to their products is a lengthwise lap evenness tester which utilizes the regular "Uster" evenness tester as amplifier and recorder. Some of these have already been installed in this country.

In this connection, it might be observed that the prewar eminence of the Germans in textile testing has passed to other countries. This condition may be only temporary. Although time did not permit us to visit any German textile research laboratories, it is apparent from their publications and textile research journals that they are working very hard to regain their former excellence in the research and testing field. Most of us who visited a number of German cotton textile mills will agree that in a few years the competition from the Germans in research and production will be hard to beat.

The efforts in France, Italy, and the Scandinavian countries shall have to be omitted for the sake of brevity rather than because of the unimportance of their work. Their approach to textile problems is basically the same as that employed elsewhere.

In conclusion, the opinion might be expressed that, in general, fundamental research on cotton fiber properties in Europe excels ours in quantity and at least equals ours in quality. In some lines of research we are stronger than they; in others we are weaker. On the whole, their superiority can probably be traced to several factors. They depend more on cotton and other natural fibers because of the lag in their man-made fiber industry. Secondly, they have governmental subsidization of textile research by direct grants and compulsory research contributions. Finally, their research personnel have a greater sense of devotion and dedication to a given line of work than we do. This situation makes for a more stable research environment which encourages fundamental and thorough research work.

In the field of testing methods and instruments, the Europeans would probably be judged to be on a par with us. They have developed good sound test equipment, some of which we already use, and some of which we would do well to adopt. Possibly their readiness to adopt certain test methods is related to the lower labor costs for laboratory technicians. We encountered one instance of a research program on neps which would be impossible in our laboratory in Princeton because no one would stand for the labor costs involved in the method being employed.

Certainly we have not yet reached the stage at which we can sit back in our easy chairs and look with smug satisfaction at our research program. We still have a lot to learn in textile research, and not too much with which to learn it.

Literature Cited

1. Bracewell, G. M., and Greenhalgh, K., *J. Textile Inst.* **44**, T266–92 (1953).
2. Dakin, G., Foster, G. A. R., and Locke, J., *J. Textile Inst.* **43**, T545–62 (1952); *J. Textile Inst.* **44**, T544–69 (1953).
3. Gregory, J., *J. Textile Inst.* **41**, T1–13, T14–29, T30–52 (1950); *J. Textile Inst.* **44**, T499–514, T515–33 (1953).
4. Morton, W. E., and Nield, R. N., *J. Textile Inst.* **44**, T317–34 (1953).
5. Waggett, G., *J. Textile Inst.* **43**, T433–42 (1952); *J. Textile Inst.* **43**, T380–95 (1952).

Methods of Selecting, Blending, and Cleaning Cotton as Practiced in European Mills

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THE COTTON PROBLEMS of European mills as observed by members of the National Cotton Council Technical Mission to Europe during its visit last June make the problems faced by American mills seem small by comparison, and it was encouraging to see the ingenuity and determination with which they were being attacked. American mills complain of the problem of maintaining an even-running mix, particularly in crop years when there is variation in cotton character from point to point, and even from picking to picking from the same point, but at least they are dealing only with American Upland cotton grown from a limited number of seed varieties and under weather and soil conditions which do not vary too widely. European mills, on the other hand, must attempt to maintain even-running mixes while using cotton from as many as six different countries, grown from different seeds, in different soils, and under different climatic conditions. The principal cottons found in European mills are American, Egyptian, Uganda, Turkish, Pakistan, Congo, and Brazilian. Most European mill men expressed a preference for American cotton in carded work, but added that at a price differential of from 2 to 3 cents a pound, and with a shortage of dollars, they could not always afford to buy it. They stated, however, that they were able to obtain an excellent cotton from Pakistan which, while not quite equal to American cotton in some respects, was extremely satisfactory in that it showed a high Pressley break and a good Micronaire reading.

Although some excellently operated warehouses were observed, in general cotton handling in European mills is not mechanized as much as it is in this country. In one German mill American lift trucks with grab attachment were being used for handling and stacking cotton. The warehouse in this plant was of modern fireproof construction with a saw-toothed roof, and was adjacent to the opening room. Cotton was neatly stacked by 100-bale lots, with wide aisles between the lots. Most warehouses visited had hand-operated stacking devices similar to those commonly in use in the United States before World War II. A number of mills had overhead traveling electric hoist systems for stacking and handling bales. In France a mill was visited which had an open front cotton storage shed of modern fireproof construction, with an excellent overhead handling system. In addition, this warehouse had a sprinkler system which enabled a curtain of water to be thrown between bays of the warehouse. Cotton was stacked in 100-bale lots by country of origin. One particularly ingenious example of the way in which postwar problems are being overcome was observed in Germany at a mill which had been completely destroyed during the last war and rebuilt since 1945. This mill had been unable to have their railroad siding restored, so they were loading freight cars of cotton onto flat-bed trailers at the railroad station, hauling them to the mill warehouse, and unloading them there.

Although some European mills are starting to test cotton for Micronaire and Pressley strength and are also using the Fibrograph, this type of testing is not at present done on the same scale as in the United States. Some mills are sampling 10% of each lot for strength, length, and fineness, and one or two are doing 100% Micronairing. A number of mills are starting to buy on guaranteed fiber specifications, and are merely sampling lots for check tests as received. Very few cotton classing rooms such as are found in American mills were observed. The general practice is for European mills to have their cotton classed in the port by an agent or controller who is hired by them and whose class they accept. One Belgian mill which was visited has an elaborate cotton testing program. In addition to the usual fiber tests, a spinning test is run on each lot of cotton received. The classer's samples from the port are thrown into a small blending feeder, which is allowed to run for about 10 min. without the doffer operating. After

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the samples have been tumbled about for this period, the doffer is started up and the cotton is delivered into a box. From here it is taken in small batches and carefully weighed out to a predetermined standard weight. These standard-weight batches are then placed behind a conventional cotton card on a feed apron which is marked off in approximately 18-in. lengths. Each weighing is spread evenly between two marks on the apron so that it approximates the weight per yard of the standard mill lap. This method of feeding the card is continued until the entire blend has been carded. The resulting card sliver is split into six lengths and fed through a draw frame. The drawing sliver is again separated into a number of lengths and made into roving, and finally ten bobbins of yarn are spun for testing. In this way the mill gets an actual spinning test on each lot of cotton, and can put a quality designation on the lot. The blends for the mill are made up so as to give an even-running spinning quality.

Many different methods of making up mixes were observed, with the size of mixes varying from 20 to 60 bales. In some cases mixes were all of one growth, while in other cases four or five growths were included in a single mix. One noticeable difference between mills equipped with European machinery and the conventional American opening room was the use of long lattice aprons in back of the bale breakers or blending feeders. Even mills using American equipment had added aprons to the blending feeders. One particularly interesting blending layout consisted of four feeders, each with a 20-ft. lattice apron behind it. The mix consisted of 60 bales—15 lined up in back of each feeder. In feeding the blend, the operator took a thin layer from each of the 15 bales and dumped it into a cart. This cart was then pushed up to the apron, and the layers from the 15 bales were dumped on the lattice. The operator then repeated this procedure until the lattice was filled with a number of cross sections of the 15-bale mix. The lattice was controlled by a swinging rake in the bale breaker so that cotton was fed only when needed, eliminating the human element. In another mill, the layout consisted of five Saco-Lowell F-7 feeders equipped with lattice aprons, with 6 bales back of each feeder, making a 30-bale mix. The operator took a 2-in. layer from each bale and laid it in a stack on the apron.

The principal European opening and cleaning systems observed during the tour were British, German, and Swiss. The two Continental systems differ principally from the British in that they have two-beater picker units, whereas the British use single-beater pickers. The British and German systems resemble each other in that the systems are divided into the following main parts: (*1*) feeders or bale breakers delivering onto a feed table, (*2*) vertical opener fed by hopper feeder, and (*3*) opener unit fed by hopper feeder and consisting of at least two cleaning points, each with a cage section.

The British system, manufactured by Platt, usually consists of a number of feeders (four at most) delivering onto a feed table and thence into a hopper feeder, which in turn feeds a porcupine beater, followed by a vertical opener. From here the cotton is drawn by a condenser and delivered into another hopper feeder, which in turn feeds a double opener consisting of a Buckley beater section, a cage section, a three-blade beater section, and another cage section. Following the double opener, the line splits and the cotton is drawn by two condensers through a two-way distributor and delivered into two hopper feeders, each of which feeds a one-beater finisher picker section with either a blade or Kirschner beater and a lap head.

The German system, manufactured by Trutschler, uses double hopper feeders before the vertical opener and before each picker section, with a single hopper feeder before the opener unit. The opener unit in the German system has two porcupine beater sections, each followed by a cage section.

The Swiss system, manufactured by Rieter, uses a porcupine opener followed by a hopper feeder which immediately follows the feed table. From here the cotton is drawn up into a cleaner of their own special design, which is in tower form with a condenser at the top. The cotton moves downward through three beaters and then passes from this machine to a vertical opener. Following the vertical opener, the line divides into two sections, each feeding a two-beater picker.

The most common practice in all three systems is for four hoppers to feed one opening line, which in turn feeds two pickers through a two-way distributor. Opener lines usually have a production rate of 800 lbs./hr. In some cases, three pickers are fed from one opening line, but the former layout is the most common. The number of cleaning points varies in all three systems, according to the type of cotton used, from as many as 7 for extremely low-grade cot-

tons down to 3 for high-grade and long-staple cottons. The usual setup for medium grade American cottons is a 5-cleaning-point unit.

Elaborate opening and picker room controls were observed in some mills, consisting of a switch panel containing all the motor controls for the opening and picking system, so set up that no machine could be started until the previous machine in the line was filled up. Likewise, when any machine in the line is full, the flow of cotton is cut off at the previous unit. In connection with these control panels, electrically lighted diagrams of the machinery are used, which indicate which machines are operating. By watching the action of the lights in the diagram, the room foreman can see how the system is functioning. Due to the many different types of cotton which may be run in one mill, bypass systems are extensively used so as not to overmachine the cleaner and longer stapled cottons. In a French mill, transparent Plexiglas sections had been put into the cotton pipes at the outlet of each cleaning unit so that any choke-ups in the line could be spotted quickly.

European mills are forced to make short runs and are at a disadvantage compared to American mills in that they are not able to run long enough on any one mix or yarn organization to really establish optimum conditions. This shows up in the fact that they often use bins to store their cotton after opening because the runs are so short. Not only do they constantly have to change from one cotton mix to another, based on the availability and price of various growths, but they are also constantly changing from one yarn number to another or from one construction to another, with a consequent loss of efficiency.

As a result of constant changing from one growth of cotton to another, and the fact that they may be obliged to mix a number of growths of cotton or to cover up unsatisfactory cotton which they cannot reject but must take in at an allowance, European mills have learned to blend with great care. Particularly in Germany, blending seems to be in series rather than in parallel—that is to say, there are a limited number of feeders discharging onto a feed table, but all through the opening line there are double blending hoppers which they feel give them good blending action. Another feature of European opening lines which is quite different from those in America, and which European mills believe gives them even running blending, is the use of the long lattice apron at the back of the blending feeders.

The general feeling among the members of our group was that the Europeans are doing a good job of overcoming their problems of blending and cleaning cotton.

Developments in European Cotton Processing Methods

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EUROPEAN textile mills are confronted with two problems which are not found, in general, in this country. One is the necessity of using cottons from many countries, all packaged in high-density bales. The other is the practice of processing a multitudinous variety of yarns, manufactured to the customers specifications. Competition is keen, and orders are accepted for small lots of yarns—sometimes as small as 500 lbs.

These two problems have had a noticeable effect on mill equipment and processing methods. A third factor, the labor situation, also influences European machinery in that equipment is usually designed for maximum production per spindle, rather than per operator, as is the American custom.

Opening

European opening rooms are considerably more complicated than their average American counterpart. The opening rooms may be divided into several lines of equipment, each designed to process different types

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of cotton mixes, or, more common, each machine in a single elaborate line of equipment is installed with a bypass, which provides a flexible organization capable of handling all mixes. In order to keep track of the processing organization being used, some mills have an electrical control and indicating board at a central location which shows, by means of appropriate lights, the sequence of the machines and which machine is operating at any particular moment. Such a control setup is especially valuable when a number of mixes are being processed in sequence or simultaneously on several lines.

Two opening systems are popular. The first opens and blends the cotton through several machines which discharge into fireproof bins, where the cotton is allowed to bloom for 24 to 72 hrs. These bins may hold 20 bales, and a mill may be equipped to store from 40 to 200 bales. Following the storage period, a second opening room removes additional trash, and then the cotton is conveyed to the picker room for further processing.

The second system utilizes a straight-through flow of cotton from opening to picking. More cleaning points are required than when the storage bins are used. Each system has obvious advantages.

A typical opening line, with storage bins, consisted of two bale breakers in parallel, a Crighton opener, and six 15-bale bins. From storage, the cotton was processed through two 41-in. Buckley beaters in tandem, two hopper feeders in tandem, and a porcupine beater, and then distributed among three 2-section pickers with a 3-blade beater at 900 r.p.m. and a carding beater at 750 r.p.m. The opening line production was 1,000 lbs./hr., and the picker room 333 lbs./picker hr. Six cleaning points plus two bale breakers and two hopper feeders produced severely curled laps, yet the card web was quite satisfactory and was reported to have 12 to 15 neps per 100 sq. in.

A representative system without storage bins had four hopper feeders, Crighton opener, porcupine beater, Crighton opener, porcupine beater, Superior cleaner, Crighton opener, belt distributor, and two 2-section pickers with 2-blade beaters in each section. There were eight cleaning points in addition to the hopper feeders. The picker lap was rough in appearance, but an acceptable card web was produced for coarse yarns.

As mentioned earlier, the necessity for processing high-density bales causes European mills to subject cotton to relatively severe opening treatment. However, the trend is toward obtaining improved opening and blending through the use of hopper feeders instead of bale breakers, and reducing the number of beaters by the installation of more efficient cleaning equipment.

Carding

An interesting point to consider is the satisfactory card sliver produced from relatively rough picker laps. There appeared to be several reasons contributing to good carding. Most textile buildings are of steel and masonry construction, and the cards are solidly anchored on a firm foundation. The condition of the cards was usually excellent; the equipment might be old, but the clothing was tight and well ground, flats were true and clean, and doffer combs were straight. Close settings were maintained; for example, one mill claimed to hold a .003 in., .003 in., .003 in., .005 in., .005 in. setting of the flats from back to front; .005 in. was not uncommon, and .007 in. was standard. On the other hand, the newest and most modern mill visited used .012 in. to .010 in. settings because they thought these produced the best results.

Carding rates were conservative, ranging from 8 to 11 lbs./hr., with cylinder speeds of 160–165 r.p.m. Stripping was done about three times per shift, and pneumatic strippers were fairly popular. One mill had an elaborate arrangement whereby the various card and opening room wastes were sucked through lines to a central room in the basement, where the waste was classified and baled for selling.

Metallic card clothing is rather common in Europe. France was said to have 25% of its cards with metallic clothing, and many metallic cards were seen in other countries. Opinions varied, but it appeared to be the consensus of opinion that the strips saved by using metallic clothing more than compensated for the excess fly and dust in the card room. Product quality was said to be good, with nep count lower than with fillet wire.

With either type of card, it seemed that operator skill and good maintenance were relied on to overcome any possible discrepancies in picker lap quality.

Drawing

Two developments observed on drawing frames are worthy of comment. One was a new type of fluted roll which, combined with a slight tension draft in the middle drafting zone, was reported to produce a more uniform drawing sliver. Decreases

in coefficient of variation of from ½% to 1% were reported.

Likewise, improved uniformity was obtained by using a 3-over-4 arrangement on draw frames and combers. In the break-draft zone a large, self-weighted top roll rides on the two back rolls. The roll resembles a 4-in. diameter steel shaft with a ¼ in. thick covering. Results from a carefully controlled test of one mill indicated a reduction of 1% in coefficient of variation.

A good many mills were changing over to sliver lappers and 16-ends up bicoil drawing frames in order to eliminate one process of drawing or one process of roving, or both. In two cases where the old system of 400 doublings was replaced with the new system of 80 doublings, this type of organization was reported to produce yarns of increased uniformity and decreased strength. Production costs were lower.

Spinning

In the spinning department, an observer is impressed by the many types of drafting systems in use. Double apron and single apron, top apron and bottom apron, four roll and three roll, and 3-over-4 systems were all recommended by their operators. The mills themselves are experimenting with modifications of their own design. In one mill of 20,000 spindles, six drafting systems were used to manufacture various yarn constructions.

Most frames were old, but many had been reconditioned with new drafting systems. The cost of reconditioning and change-over was said to run from $9 to $12 per spindle.

One increasingly popular frame uses a 3-over-4 drafting system, 50° tilt to the rolls, with the front roll centered over the spindle, anti-balloon guides, self-weighted back rolls, and a total draft of 46.

Another frame has a dual motor system—a small motor for the first part of the doff and a larger motor to complete the doff. A stationary ring rail and traversing spindle rail provide a fixed yarn length. A separate fractional horse motor automatically raises or lowers the spindle rail to the correct doffing position when the frame is ready to doff. Total draft is 50.

Another manufacturer's frame has easily removable ring rails, so that changing rings is quickly done by inserting an entire new rail with different size rings.

The discharge from pneumatic suction systems for end breakage is sometimes applied to cooling the driving motors of spinning frames.

It was interesting to note the differences in rear-zone draft settings. Mills in several countries used back drafts of 1 to 2.5, depending on whether the yarn is carded or combed. Others insisted that drafts of 1.04 to 1.20 were preferable.

One development in top-roll weighting worth mentioning is the increasing use of pneumatic and hydraulic systems. The deflection of a small hose under air pressure to weight the rolls was reported to be very successful; weighting was said to be uniform and could be regulated or eliminated by the turn of a valve. For the most part, back rolls are self-weighted.

Research on textile machinery seems to be concerned largely with developing new equipment specifically for synthetic fibers or modifying cotton machinery to process synthetic fibers. The Shirley Institute is still engaged in considerable research on processing equipment for cotton. The commercial model of the Shirley opener, discussed by Mr. Dakin at this Clinic last year, was not yet available for inspection at the time of our visit.

Miscellaneous

Of possible interest to American management are the schools to train supervisors which are operated by groups of mills. Equipped with processing machinery and testing instruments, the schools usually require 3 years attendance for overseers and 4 years for superintendents.

No outstanding textile technological developments were observed in Europe. There seemed to be considerable reluctance by many mills to depart from traditional processing methods, to accept or even to experiment with new ideas, or to apply the findings of their own research institutions. However, in general, European processing methods and machines are basically the same as those of the United States.

Quality Requirements and Cotton Fiber Procurement Practices in Europe

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IN past years, American cotton enjoyed a comfortable supremacy in the European markets. It is common knowledge that American cotton was purchased by many European mills to "sweeten their mixes," indicating that they considered it superior. However, in the past few years, the situation has changed and the high position of U. S. growths is jeopardized by the post-war technological advances in formerly "backward" agricultural nations. Other countries have advanced to the point where their methods of growing, harvesting, and ginning cotton are almost as good as ours, and many foreign growths are comparable in quality to American cotton. Indeed, they purchase American seed, taking advantage of years of painstaking work in breeding new varieties to increase yield and improve fiber qualities.

The European mills have watched this change in the world's cotton picture with eager interest. Every American shipper who sells to Europe has an agent, or in the case of a large shipper, a branch office, who does the "leg work" of calling on the mills and selling them cotton. Success in any European market depends upon this agent. The agent may handle only one American shipper's account or several, depending upon the agreement entered into. However, there is no limit as to the number of exotic shippers he may represent. He usually sells strictly on a commission basis; therefore, it ordinarily matters little to him whether he sells American or Turkish cotton, for example. As for the mill man, he can examine cotton from every cotton producing country, and, where the quality is the same or similar, the price is quite naturally the deciding factor. Right now, they are keenly aware that they can buy exotic cottons at cheaper prices because of lower production costs, and that they do not have to touch their valuable dollar reserves. Also, other cotton producing nations do not have a government loan to keep prices at an artificially high level. It is a fact—American cotton is losing ground!

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In an attempt to regain lost ground and push American cotton forward, some few progressive cotton men have opened the door to an entirely new field: scientific fiber analysis. Some mill men have looked through the door, liked what they saw and entered, wholeheartedly in favor of fiber testing. The normal conservative nature of mill men in all countries prevented many more from taking advantage of these new methods. Nevertheless, they are slowly warming up to the idea, and much progress has been made.

The European system of quality control and inspection is quite different from our own. Most mills over there do not hire experienced cotton classers to handle their receipts. Instead, they depend upon a "cotton controller" at the port of import. It is the duty of this controller to receive the shipments, supervise the weighing, sample the bales, and make quality outturn reports to the mills. It is on the basis of these outturn reports that the mills make claims for amicable settlement of quality differences or go to official arbitration to settle the amount they are to receive for bales they feel are not equal to contract description. They do not have the right to reject the cotton, except in rare instances where it is agreed upon by the shipper. Therefore, the mill must accept the cotton as delivered and make the best of it. The controller does not enjoy the fortunate position of the American mill man, who can reject the cotton, and get prompt replacements, for in Europe it takes from three weeks to a month to get more cotton. It is for this reason that they have taken readily to the idea of scientific analysis and laboratory tests. By buying on certain guaranteed fiber instrument readings, they will have added insurance that they will get the quality they need.

For checking purposes those mills that do not have their own laboratories must rely on a controller. The situation has not yet progressed to the stage where all controllers have laboratories, but some important ports do have them—Bremen, for

example, has three—and it is profitable for those who have laboratories to do testing for the others. As yet there are no arbitration provisions made for not complying with contract terms as to fiber characteristics. The only deterring factor is the threat to cease buying from those shippers who may not live up to their contract obligations. This is a strong force, particularly during periods of intense competition.

Logically enough, if the controllers and mills can test American cotton, they can also test foreign growths. They are now in a position to find the hidden values in these growths as well. Again, the edge of our advantage has been dulled, and it is only by our seniority in this field that we are still ahead. Mills in every market have become increasingly interested in laboratory control, and you find such instruments as the Micronaire, the Pressley tester, and the Fibrograph to be common equipment. The terms used in connection with these instruments are becoming everyday language among European cotton men. By far, the most common requirement is the Micronaire reading, with the Pressley running a close second. It is only a rare instance when a contract is made specifying a range of maturity or Fibrograph readings, or Shirley waste indications. Naturally, the time-honored system of classifying cotton according to grade and staple is still the dominant factor and it will probably remain so for years to come.

Some of the quality requirements run as follows:

Grade: mostly high grades, except a small percentage of California low grades for technical yarns.

Staple: mostly 1 in. to $1\frac{3}{32}$ in. for Germany; a substantial quantity of $\frac{7}{8}$ in. to 1 in. for England; and $1\frac{1}{32}$ in. to $1\frac{1}{16}$ in. for the other countries.

Fineness: the European spinners are quite aware of the effect of fiber fineness, and by far they prefer 4.0 and higher, on the Micronaire. They are especially cautious about neps, and thus favor the coarser cotton. Most German contracts specify "Noppen und Nissen Frei" (Free of Neps and Nits), and they are quite particular about it.

Strength: nearly all insist on high strength, and those making technical yarns are especially insistent. In many cases the fiber strengths asked for are definitely higher than actually needed, and some requests are difficult to fulfill. This situation should spur on the development of the Hopi-Acala and other super-strength cottons.

Germany and Switzerland appear to be in the lead in their acceptance of fiber specifications. France is showing interest, but Spain is still not in the class of converts. Curiously enough England, whose scientists were some of the earliest pioneers in fiber technology, has been slow to adopt new techniques on a broad scale.

Summarizing, we need export outlets to take off the surplus production of American cotton. The American shipper has two tools with which he can fight foreign competition. First, he can offer the mill cotton which is quality controlled from the original source through fiber specifications, whereas the mill man buying exotics does not know what he is getting until the cotton reaches his or his controller's laboratory. Second, the shipper can use the new methods of fiber testing to establish a confidential relationship with his European customers, whereby the shipper will recommend and furnish qualities which will exactly fit the spinner's needs. Through such teamwork the spinner obtains greater efficiency and more uniform quality merchandise, both of which make him a more satisfied customer of American cotton.

Cotton Technology and Manufacturing Practices in the Orient

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COTTON has been used as a textile fiber in the Orient for thousands of years. It was a major item in wearing apparel and household fabrics in countries like India long before it was known to England and the western civilizations. It is only natural, therefore, that the technology of the Orient is somewhat different from that in the western civilizations.

Cotton fabrics were manufactured in the home in the early days. A family with simple equipment, including the Indian spinning wheel, made up the core of the industry. This is still true to some extent in the hinterlands, and its influence on manufacturing, particularly fabric designs, is still widely felt throughout the Orient. Many lovely fabrics are handmade, and artists designing for the big manufacturing centers are now studying hand-woven fabrics, particularly the variations which only recently were considered to be defects, with the idea of being able to reproduce them mechanically. American merchants search the small villages and the back-street shops in the large cities for exotic fabrics typical of the Orient. In India, beautiful figures of 18 carat gold are woven into silk fabrics. Patterns designed by artists with no training except their imaginations are made by dyeing the yarns by hand before weaving, and then weaving them into lovely patterns in wool, silk, and cotton.

Egypt

Although the modern concept of research is relatively new to much of the Orient, intensive study has been made throughout the centuries by individuals and small groups. Concentrated laboratory research was established in Egypt about 1922 at Giza, just across the Nile River from Cairo. The Giza laboratory was under the direction of Lawrence Balls, one of the leading fiber technologists of our time. He wrote books showing a very broad knowledge of cotton fiber technology as early as 1923. He was assisted by Dr. Brown, the author of *Egyptian Cotton.* Dr. Brown developed Karnak and the new Giza cottons which are so popular in mills today. At the outbreak of the present revolution in Egypt, most English people who had not been in Egypt for more than 15 or 20 years were forced to leave. Dr. Brown and Lawrence Balls were among this group. Brown was stoned by a group of students and was seriously injured. Balls was asked to leave. Hancock, one of the cleverest spinners in a research laboratory anywhere, died in an automobile accident.

The laboratory at Giza emphasizes spinning tests and makes fiber tests only on promising varieties. They spin all of the new strains, and measure the fiber properties on only those that appear to be of interest from the point of view of spinning quality. Hancock developed a rapid method of spinning small samples. He could spin 60 g. or more of cotton on standard equipment and get a reasonably accurate measure of the spinning quality. His standard test in the laboratory used less than 1 lb. of cotton. The laboratory in Giza is now under the direction of native Egyptians who were trained under Balls, Brown, and Hancock.

The Alexandria Testing House is now planning a spinning laboratory that will spin from 100 to 200 or more samples per day.† They will furnish the data obtained to the buyer of the cotton. This is the first attempt of the cotton industry in a given country to modernize cotton classing to the extent that the value of a bale of cotton will be determined solely by its fiber properties and spinning quality. This is the goal of the Alexandria Testing House in Alexandria, Egypt. It is anticipated that they will find it difficult for some time to come due to the trade practices throughout the world of buying cotton on classers' descriptions. If, however, this program is accepted, it is likely that the Egyption cotton will be the first to be sold on the basis of laboratory tests only.

The spinning laboratory in Alexandria will be the

* Director of ACCO Fiber & Spinning Laboratory system.

† Dunkerly, F., Design for Quick Production of Spinning Tests, *J. Textile Inst.* **41**, 148 (1950).

largest of its kind anywhere in the world. There are laboratories that can spin a larger volume of cotton, but no other laboratory, to the author's knowledge, will be equipped and staffed to test so many samples per day. It is indicated that the Alexandria spinning laboratory will be under the direction of Frank Dunkerly, who was trained by Balls and Hancock.

Although there was very little information available, the author was told that the Egyptian government is encouraging private firms to install cotton mills in Egypt. They are of the opinion that Egypt should spin, weave, and finish more of their fine cottons and export the fabrics.

Pakistan

Pakistan is a relatively young country, but it inherited a considerable part of the cotton and most of the jute production of old India. Essentially all of the manufacturing, particularly the cotton and jute spinning, was in what is still India. The Pakistan people, therefore, found themselves with raw cotton and jute but few cotton mills. Their first step was to install new spinning equipment. They have increased their spindles and looms about 350-fold in the past 2 years. They have also built one of the most modern research laboratories of its kind. The laboratory will include ginning, fiber technology, spinning, weaving, and finishing. It will also include research work in biology, chemistry, physics, and fiber technology. This laboratory is under the direction of Dr. S. M. Nawaz, who was trained in England and has visited in the United States. The people of Pakistan are progressive, and it is quite likely that they will go forward with this new venture.

India

India is the oldest of the cotton-spinning areas recorded in history, and has followed very closely in the footsteps of the Shirley Institute, England, in their research program. The Indian Central Cotton Committee laboratory at Matunga, Bombay, was organized by Dr. Turner of England in about 1922. Dr. Turner is one of the foremost fiber technologists of the world. He did basic research in spinning in the Bombay laboratory that is still of interest. He, like many others who worked in the Orient, has returned to England; and the laboratory is now under the direction of Dr. Nanjundayya. He has a staff of native Indians, some of whom have been trained abroad and others of whom were trained by Turner and his followers in the Bombay laboratory. These people have progressed slowly, but have developed some new equipment and methods of testing which are not used elsewhere.

The laboratory in Bombay has been used primarily by the cotton breeders to improve the cottons of India. The information, but not the methods, has been used by the mills. This may have been due, to some extent, to the time-consuming and expensive methods used. The impression was obtained that Dr. Nanjundayya proposes to develop faster methods and carry his work into the cotton mills.

The Indian mills have adopted some American techniques. The most progressive mills have at least a Micronaire, and some of them have Pressleys and Fibrographs. Since India has become independent, they have developed a long-range program of cotton research. The big mill center in Ahmedabad has organized into the Ahmedabad Textile Research Industry's Research Association (A.T.I.R.A.). The program at A.T.I.R.A. includes teaching, fiber testing, spinning, weaving, finishing, and research on all phases of cotton including cotton breeding. They will work with the Indian Central Cotton Committee laboratory in Bombay on breeding problems.

In addition to this magnificant cotton research center in Ahmedabad, the mill association in Bombay has recently set aside a sum of money for a research institute in the Bombay area. It is not yet clear whether this laboratory will be an addition to the now existing facilities at Matunga or a new organization. When they combine modern techniques and the best equipment available with the rich background of textile development in the Indian area, we may expect at least something different from our Eastern neighbors. Here may be observed some of the most beautiful fabrics to be seen anywhere. The aesthetic taste of the cultured oriental is deep-rooted, and his art has a delicacy that is unsurpassed.

China

It is impossible to determine what is going on in Red China, but the mill people who have moved out of the Shanghai area into Hong Kong have built a number of mills. When the author was in Hong Kong in July, 1953, there were twelve medium-sized textile mills and two small ones. Some of the mills had ordered enough equipment to double their present size. Some of them have been able to make suf-

ficient profit to completely amortize the mill in two years. One mill owner said that he could now buy Japanese equipment and make a better profit on it than he could have had he bought it before the boom was over. He said the price of the equipment had fallen faster than his profits in the mill. Although the Chinese in Hong Kong are not sufficiently well organized to develop jointly financed research facilities, they are thinking about it. They have an association which is now planning a testing laboratory which may eventually develop into a research center.

Japan

Japan's textile industry has recovered since the war. The Japanese army during the war forced the mills to dismantle about 75% of their equipment. The equipment was to have been used in munitions, but due to our intensive bombing of Japanese mills, much of it never got to the smelters. After the war, however, it had rusted to the extent that it was no longer usable for cotton manufacturing. Since the war, they have replaced the old mills with brand new equipment. This equipment is made in Japan, but includes many of the new concepts from this country and Europe.

The Japanese mills are adopting all of the new procedures, regardless of origin, found to be usable in their industry. They still use young girls to a large extent in the cotton mills, and these girls are encouraged to work in the mills because of a new educational program which the Japanese have adopted since the war. A girl can go into a Japanese mill from a farm or small village and work from 3 to 4 years and come out a rather accomplished young lady. She will not only have a dowry, which is necessary for marriage, but she will know how to dance, cook, serve, and entertain. She will be taught sewing and mathematics, particularly for budget use, and may learn English, if she is so inclined. Her education at the end of 4 years will be somewhat less than that of one of our high school graduates, but nevertheless substantial. She will be better prepared, in some respects, to make a home than our high school graduates.

In addition to the new, up-to-date mills, the Japanese Spinners' Association has set up a testing laboratory in Osaka. This testing laboratory has all of the modern equipment from the United States and Europe. They test fiber, yarn, and fabric; and the data are available for any manufacturer exporting cotton fabrics. The Japanese craftsmen have been very clever in developing instruments. They have copied the Micronaire and the Pressley, and are now in the process of making a new Pressley.

Conclusion

These data tend to indicate that new upland-type varieties bred in the United States have been adapted to the Orient, and new methods of manufacturing developed here and in Europe are being used by the great masses of people in the Orient. Their desire for a better way of life and the encouragement given them by our armed forces stationed there may spur them on to new and better things. In order to prevent our methods from becoming obsolete, we should remain competitive in every phase of our great cotton industry. In the author's opinion, this can be done because we have many advantages, among which are our (*1*) more extensive educational system, (*2*) better farm and mill methods, (*3*) highly developed seed-breeding industry, (*4*) more and better fertilizers, (*5*) insect and disease controls, and numerous other methods and customs that promote good business. Should we fail to remain competitive, cotton production and manufacturing will seek the areas of low cost and high efficiency, since cotton products are used by all people.

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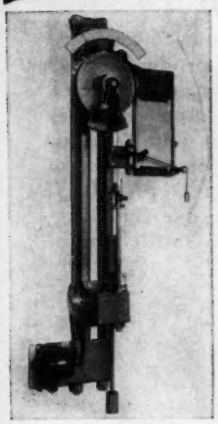

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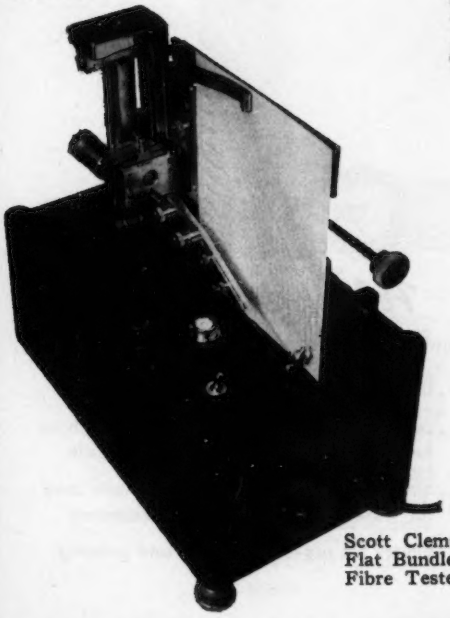

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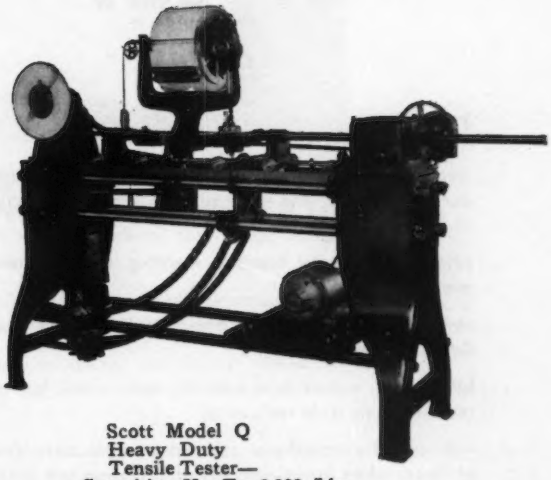

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News about

B. F. Goodrich Chemical *raw materials*

IDEAS FOR IMPROVING *Cotton* PRODUCTS

Here's a quick reference list of B. F. Goodrich Chemical materials designed to improve cotton products. Used successfully in many applications they include binders, processing size, filler, finish treatments, colors and other materials. They may give you ideas for improving or developing more saleable cotton products. For helpful technical information, please write Dept. TRJ, B. F. Goodrich Chemical Company, Rose Building, Cleveland 15, Ohio. Cable address: Goodchemco. In Canada: Kitchener, Ontario.

Check this list!

Hycar Reg. U. S. Pat. Off. *Latex*

FUNCTION

- . . . permanent warp yarn size to provide abrasion resistance during weaving; and wear resistance and color fastness to finished fabric.
- . . . after-treatment to improve wearing qualities and to provide a full hand.
- . . . carrier for specialty active agents such as fungicides and flame proofing chemicals.
- . . . binder for waxes and metallic salts used for water repellence or stain resistance.
- . . . with urea-formaldehyde resin to prevent deterioration of fibers when large amounts of U-F resin are used for crease and wrinkle resistance.
- . . . binder for pigment coloring and printing.
- . . . binder for non-woven fabrics.
- . . . after-treatment to reduce crock particularly with red naphthol dyes.

Geon Reg. U. S. Pat. Off. *Polyvinyl Latex*

FUNCTION

- . . . filler to provide stiffness.
- . . . carrier for specialty active agents such as fungicides and flame proofing chemicals.
- . . . binder for waxes and metallic salts used for water repellence or stain resistance.
- . . . binder for pigment coloring and printing.

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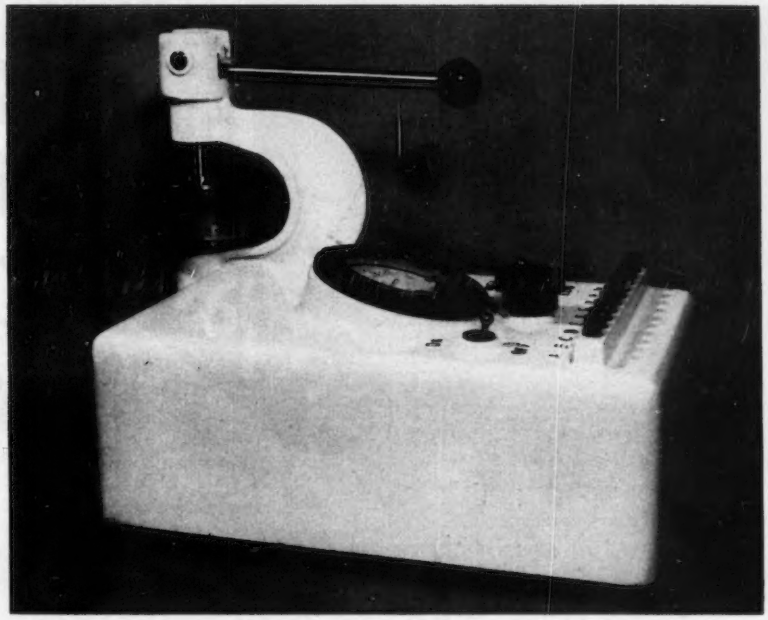

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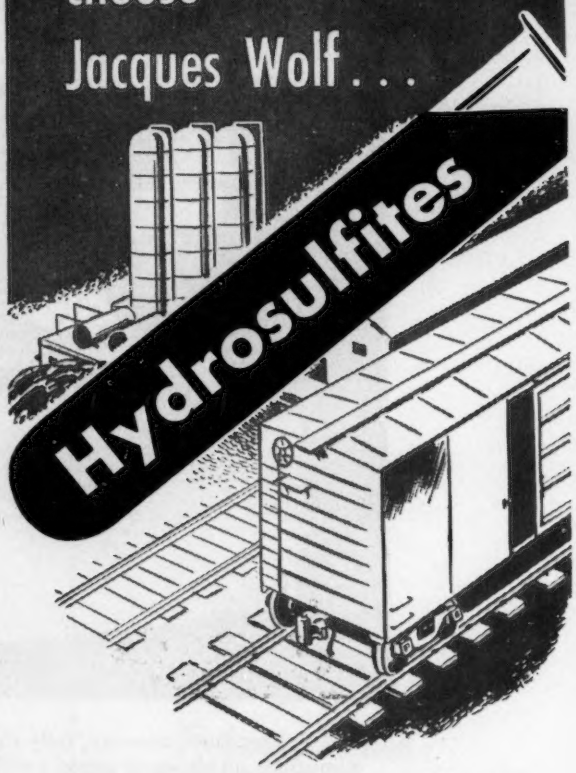

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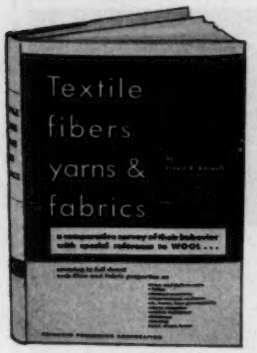

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Kaswell's book was developed from a compilation of fiber and fabric data prepared for the Wool Bureau. Using wool as a yardstick for comparing fiber and fabric properties, this material was then enormously expanded to bring you a complete study of *all* fibers, including such recent synthetics as Dacron, Vicara, X-51, etc.

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TEXTILE RESEARCH JOURNAL
Special Issues

EXTRA copies of this June issue of Textile Research Journal have been printed as well as of the April and May issues.

APRIL issue contains the proceedings of the November, 1953 annual meeting of Textile Research Institute. Papers were given on blending, "Consumer Complaints and Their Implications for Textile Research and Development," fiber structure, dyeing, and fabric finishing.

MAY issue includes the T.R.I. survey of the literature published during 1953 covering all phases of research and development. Nineteen hundred references are given.

Price of these issues: $1.50 each, or any 3 for $4.00. Extra discount on quantity orders.

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CANADIAN TEXTILE SEMINAR
Kingston, Ontario
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THE FOURTH BIENNIAL TEXTILE SEMINAR under the sponsorship of the Textile Technical Federation of Canada, will be held at Queen's University, Kingston, Ontario.

At the three-day meeting papers will be presented by well-known authorities from Canada and the United States. The program is divided into the following sections: Mill Management, Man-Made Fibers, Cotton Manufacturing, Knitting, Woolen and Worsted, Dyeing and Finishing, and Research. The keynote address will be given by Dr. W. J. Hamburger of Fabric Research Laboratories—the title "Some Aspects of the Engineering Design of Fabric Structures."

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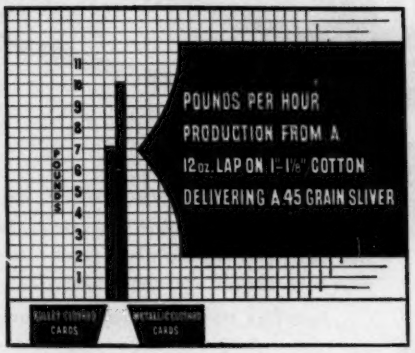

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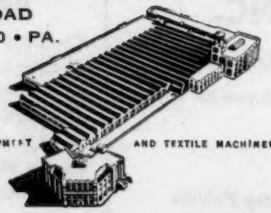

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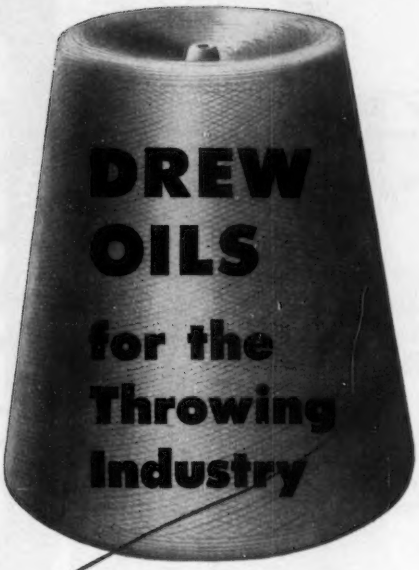
Attendance is limited and interested persons should send at once for information to:

Summer Session Office
Room 7–103
Massachusetts Institute of Technology
Cambridge 39, Mass.



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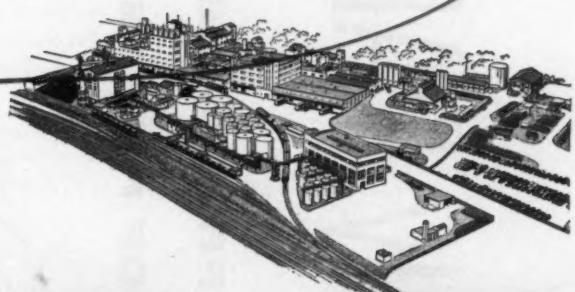

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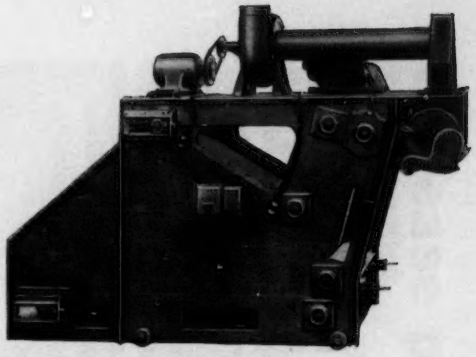

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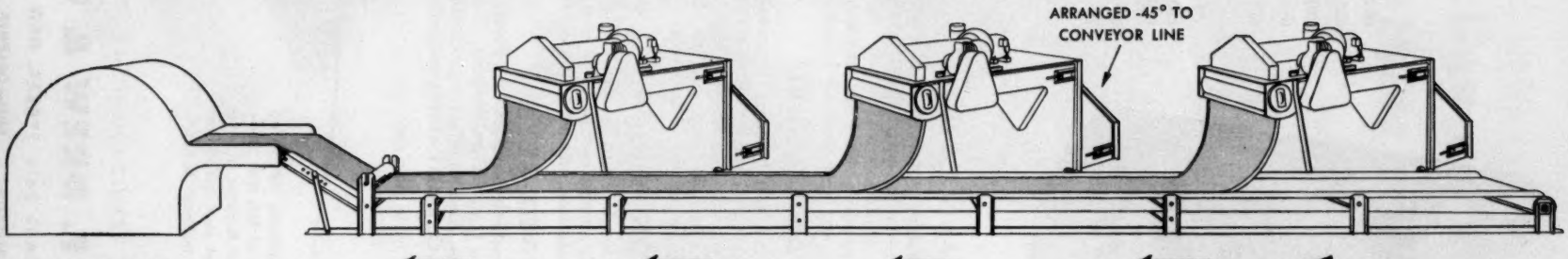

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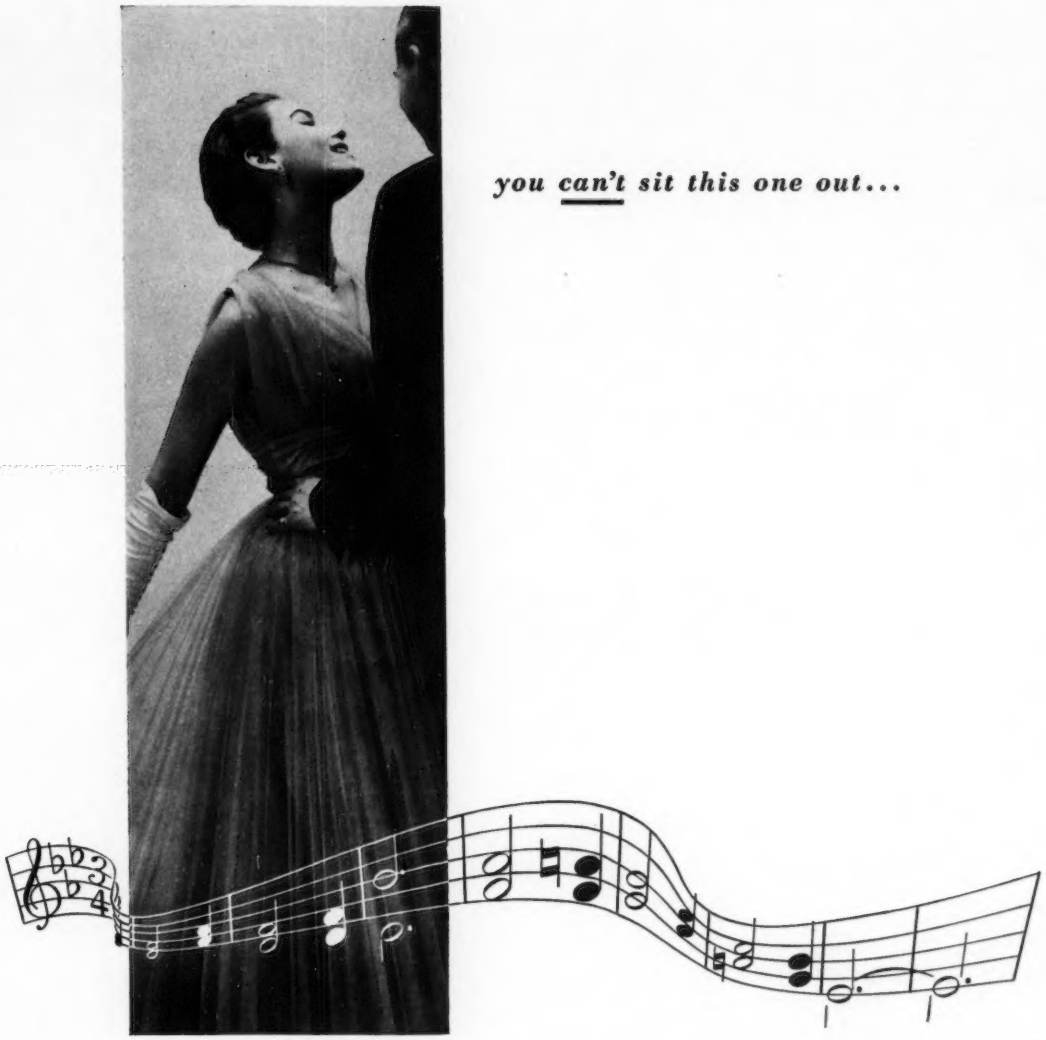
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